AD-A125 238 PLASMA CATECHOLAMINES AND STRESS ASSESSMENT IN MEN EXPOSED TO MODERATE ALTITUDES(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH R L RUSSELL 1982 1/1

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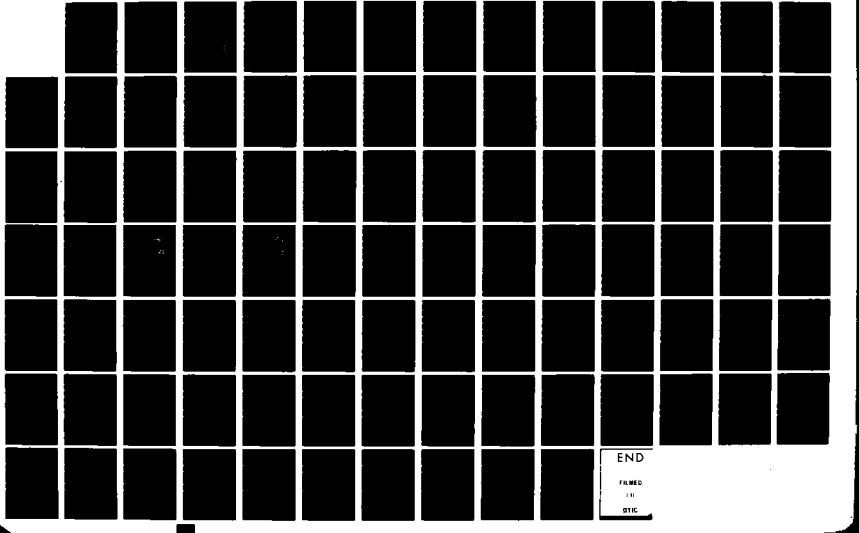

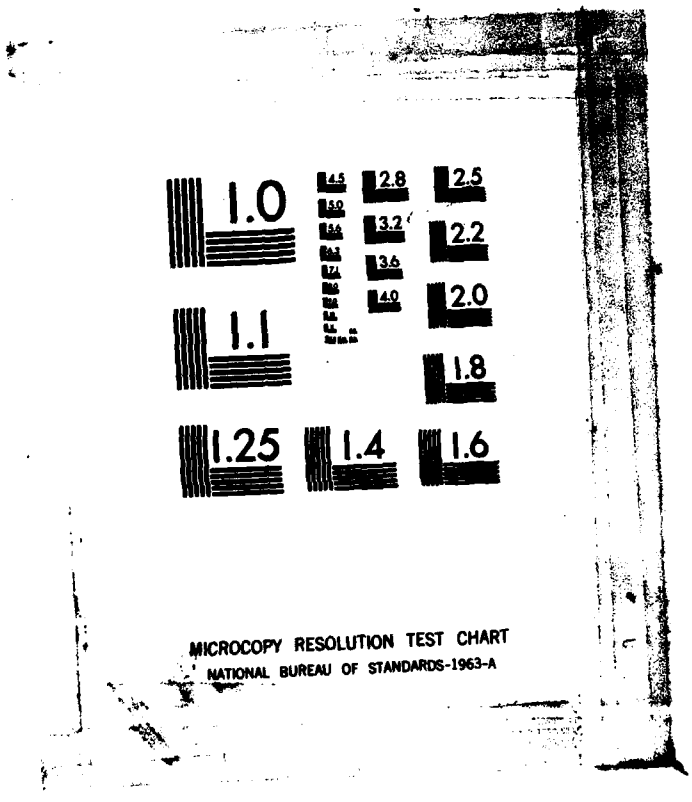
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1. REPORT NUMBER: AFIT/CI/NR 82-65T	2. GOVT ACCESSION NO.: AD A125238
	3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): Plasma Catecholamines and Stress Assessment in Men Exposed to Moderate Altitudes	5. TYPE OF REPORT & PERIOD COVERED: THESIS/DISSERTATION
	6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): Roberta Louise Russell	8. CONTRACT OR GRANT NUMBER(s):
9. PERFORMING ORGANIZATION NAME AND ADDRESS: AFIT STUDENT AT: Colorado State University	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:
11. CONTROLLING OFFICE NAME AND ADDRESS: AFIT/NR, WPAFB OH 45433	12. REPORT DATE: 1982
	13. NUMBER OF PAGES: 79
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASS
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report)

ROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

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THESIS

PLASMA CATECHOLAMINES AND STRESS ASSESSMENT IN MEN EXPOSED TO MODERATE ALTITUDES

Submitted by

Roberta Louise Russell

Captain, USAF, BSC

Degree of Master of Science, Physiology

Colorado State University

Fort Collins, Colorado

1982

(6 pages)

ABSTRACT OF THESIS

PLASMA CATECHOLAMINES AND STRESS ASSESSMENT IN MEN EXPOSED TO MODERATE ALTITUDES

Plasma norepinephrine (NE), epinephrine (E), and venous oxygen content, $P_{(O2)}$, $P_{(CO2)}$, and pH were measured in six resting males before, during, and after exposure to hypobaric hypoxia in a hypobaric chamber. Cardiopulmonary parameters were monitored during the exposures and a subjective survey of psychological stress and acute mountain sickness (AMS) symptoms was carried out. Each subject was acutely exposed to four separate pressure altitudes; 5,000 ft (632 torr), 8,500 ft (553 torr), 12,500 ft (474 torr), and 17,000 ft (395 torr), for one hour. Resting venous blood gas values did not indicate a hypoxic response at 5,000 or 8,500 ft, but hypoxemia, tachycardia, and hyperventilation were detected at 12,500 and 17,000 ft. Plasma E showed no significant changes while plasma NE increased due to altitude only during the 17,000 ft exposure. Psychological stress could not be determined from the survey data at any altitude, but AMS symptoms were experienced during the 12,500 and 17,000 ft exposures. Changes in plasma NE did not correlate with the degree of AMS experienced. A correlation between plasma NE and venous oxygen content was seen during the 5,000 and 8,500 ft exposures but not during the 12,500 or 17,000 ft exposures. It was concluded that while the 12,500 and 17,000 ft exposures elicited

cardiopulmonary compensatory changes and AMS symptoms, only exposure to 17,000 ft elicited a sympathetic response.

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Fall, 1982

AFIT/CI/NR 82-65T

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AUTHOR: Roberta Louise Russell

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THESIS

PLASMA CATECHOLAMINES AND STRESS ASSESSMENT IN MEN EXPOSED TO MODERATE ALTITUDES

Submitted by

Roberta Louise Russell

Department of Physiology and Biophysics

In partial fulfillment of the requirements

for the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Fall, 1982

COLORADO STATE UNIVERSITY

November 19, 1982

WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY ROBERTA LOUISE RUSSELL ENTITLED PLASMA CATECHOLAMINES AND STRESS ASSESSMENT IN MEN EXPOSED TO MODERATE ALTITUDES BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

Committee on Graduate Work

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ABSTRACT OF THESIS

PLASMA CATECHOLAMINES AND STRESS ASSESSMENT IN MEN EXPOSED TO MODERATE ALTITUDES

Plasma norepinephrine (NE), epinephrine (E), and venous oxygen content, P_{O2}, P_{CO2}, and pH were measured in six resting males before, during, and after exposure to hypobaric hypoxia in a hypobaric chamber. Cardiopulmonary parameters were monitored during the exposures and a subjective survey of psychological stress and acute mountain sickness (AMS) symptoms was carried out. Each subject was acutely exposed to four separate pressure altitudes; 5,000 ft (632 torr), 8,500 ft (553 torr), 12,500 ft (474 torr), and 17,000 ft (395 torr), for one hour. Resting venous blood gas values did not indicate a hypoxic response at 5,000 or 8,500 ft, but hypoxemia, tachycardia, and hyperventilation were detected at 12,500 and 17,000 ft. Plasma E showed no significant changes while plasma NE increased due to altitude only during the 17,000 ft exposure. Psychological stress could not be determined from the survey data at any altitude, but AMS symptoms were experienced during the 12,500 and 17,000 ft exposures. Changes in plasma NE did not correlate with the degree of AMS experienced. A correlation between plasma NE and venous oxygen content was seen during the 5,000 and 8,500 ft exposures but not during the 12,500 or 17,000 ft exposures. It was concluded that while the 12,500 and 17,000 ft exposures elicited

cardiopulmonary compensatory changes and AMS symptoms, only exposure to 17,000 ft elicited a sympathetic response.

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Fall, 1982

ACKNOWLEDGMENTS

I wish to express my honest appreciation to my role-models and mentors, Drs. Alan Tucker and David Robertshaw. Their continual encouragement and advice made this project a meaningful experience rather than simply a task to be completed. I wish them both the greatest success in all their endeavors and hope they continue to influence many future scholars of physiology.

A special note of thanks must go to the subjects of this experiment for without them, there would have been no project. Their patience and enthusiastic participation helped immeasurably in the smooth completion of the experiment.

I want to thank Dr. Robert Grover for allowing me to draw from his experience and knowledge in this area and Dr. Jeff Gliner for his help on the statistical analysis. Special thanks goes to those who helped in the chamber and lab and particularly to Kevin Greenlees and Dr. Marty Fettman for their technical expertise during the cannulations.

Finally, I want to thank the United States Air Force for the opportunity to participate in the Air Force Institute of Technology program which sent me to Colorado State University.

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CHAPTER I

INTRODUCTION

In the United States Air Force, more emphasis is being placed on getting maximum performance from our aircrews than ever before. With today's high performance aircraft, aircrews must now perform more technically complicated tasks, faster. Human factors in the aircrew environment is an area of great concern and the evaluation of the stressors on human performance is a part of this concern.

Stress is defined in Dorland's Medical Dictionary as "The sum of all non-specific biological phenomena elicited by adverse external influences..." (11). In the aircraft environment, there are many sources of adverse external influences which can lead to aircrew stress resulting in fatigue and decreased performance. The problems associated with hypobaria as one of these stressors has long been recognized (1,28). Though efforts to prevent exposure to severe hypobaria are put into the flying program through the use of pressurization systems and stringent regulations, our aircrews are still often exposed to mild to moderate hypobaria. The flagrant result of these exposures, hypoxia, is guarded against with the use of supplemental oxygen and pressurization. More subtle effects which could lead to aircrew stress could still be present, though never clearly defined.

Stress in animals has often been measured by monitoring the animals' natural stress response system, the sympatho-adrenal system

(7,8,14,15,24,33,42). The measurement of catecholamines has been demonstrated to be an adequate indicator of stress-induced sympatho-adrenal activity (14,42). It has been shown in several studies that hypobaric hypoxia increases urinary and/or plasma catecholamines (7,22,29,30,33,38). This increase has been interpreted to be due to an overflow from an increased sympathetic adreno-medullary secretion and, therefore, could indicate a response to hypobaric hypoxia as a stressor (7,22,30,33,38). Cunningham et al. (7) went as far as to say, "Altitude itself is the main cause of increased NE excretion..." seen in mountain climbers studied at 4,500 m (14,960 ft). What they meant by "altitude" is not clear. Since attempts to control stressors other than hypobaria (i.e. cold, anxiety, exertion) were minimal, it is difficult to ascertain the exact cause of the increased NE excretion. Also, researchers have indicated that increased NE in urine or plasma is not an immediate response but appears only after several days of exposure to hypobaria (7,33,38). A more distinct measure of catecholamine changes during hypobaric hypoxia is needed if we are to be able to use them as indicators of human stress during such exposures.

The goal of this experiment was to study the effects of a restricted scope of hypobaric hypoxia (i.e. acute, one-hour exposure to moderate altitudes), on the sympatho-adrenal response. The use of a hypobaric chamber was selected so that other stressors could be more adequately controlled. The main emphasis was to control exertion, anxiety and environmental conditions so any changes seen in perceived stress or catecholamine levels would be directly associated with the

hypobaric hypoxia. Venous plasma catecholamines along with a psychological survey were used to ascertain stress experienced in men acutely exposed to altitudes considered in the flying environment to be only slightly stressful. While exposure above 18,000 ft could definitely elicit a stress response, the more moderate altitudes were studied to determine if any measurable response was present which could lead to decreased aircrew performance.

CHAPTER II

METHODS

Six adult male volunteers (ages 22-47) were used in this study. All were in good health and physical condition and were within the ideal weight standards for their height and age (Table 1). Each of the subjects participated in voluntary light to moderate exercise (2-6 hours/week). Four of the subjects had extensive prior experience as subjects for scientific research and were familiar with exposure in a hypobaric chamber. The other two subjects were given orientation runs in the chamber and served as inside technicians during at least one exposure before they were used as subjects. All subjects were briefed not to consume alcohol for at least 12 hours before the exposure and to eat a normal breakfast, but without caffeine containing beverages, on the morning of the exposure.

Each subject was exposed to four different simulated altitudes in the hypobaric chamber. The barometric pressure difference between altitudes was 79 torr, starting with a 632 torr (5,000 ft) ground level sham exposure. The other three exposures were 553 torr, 474 torr, and 395 torr (8,500, 12,500 and 17,000 ft, respectively). The order of the exposures for each subject was randomized and not revealed to the subjects (Appendix A). A subject was never exposed more than once a week and care was taken to standardize the day of the week and

Table 1

Physical description of the subjects

Subject	Age (yrs)	Weight (kg)	Height (cm)
RA	22	81.6	190.5
KG	28	59.9	172.7
BR	32	78.0	175.3
DR	47	65.8	172.7
DS	30	74.8	177.8
AT	34	63.5	172.7
Mean	32	70.6	177.0
± SEM	3	3.6	2.8

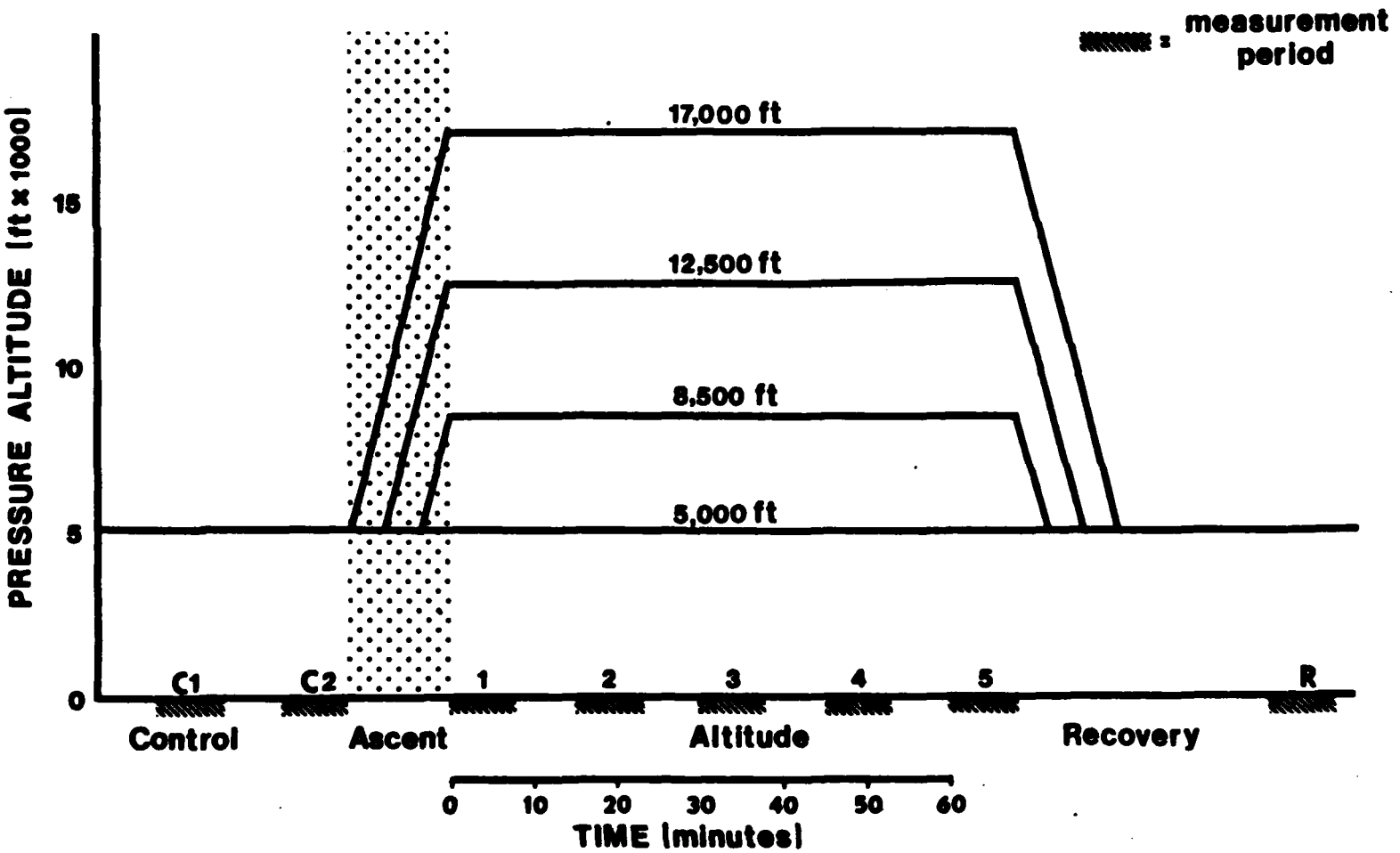
time for each subject. All exposures were in the morning and occurred between mid-October and mid-December.

Ascent and descent rates were approximately 1,000 ft/minute for each of the altitude exposures. Care was taken not to disclose to the subject the peak altitude of any exposure. This was accomplished by maintaining the same time from door closure to peak altitude for all exposures; i.e. for the 8,500 ft and 12,500 ft exposures ascent was delayed after "start" so, with an ascent rate of 1,000 ft/minute, peak altitude would be reached in 12 minutes, the time it took to reach the maximum altitude of 17,000 ft (Fig. 1).

The subjects rested continuously in a semi-supine position and were allowed to read, rest or write during the exposures. Music, of the subject's choice, was played during the exposure. Chamber temperature was 18-20°C and the subjects were covered by a sheet if they felt subjectively cold. For two of the subjects, a heating pad was used over the forearm to aid venous blood sampling.

Each experiment started with an experienced technician placing an indwelling catheter (Deseret, angiocath, 20 ga, 1.25 inches) into the median cubital or cephalic vein. Subjects KG, DS, and RA proved difficult to catheterize, KG and DS on their first exposure only and RA on all of his exposures, so 15 minutes extra rest time was given to these subjects to allow them to recover from the trauma. After the catheter was in place, the subject was moved to the chamber and instrumented for a three limb lead electrocardiogram (ECG). He was then allowed to rest 30 minutes (except where noted above) before the first control measurements were taken.

Figure 1. Exposure profiles for the four different altitudes. Speckled area represents ascent time; from door closure to reaching peak altitude.


= measurement period
17,000 ft
12,500 ft
8,500 ft
5,000 ft
PRESSURE ALTITUDE (ft x 1000)
15
10
5
0
C1
C2
1
2
3
4
5
R
Control
Ascent
Altitude
Recovery
0
10
20
30
40
50
60
TIME (minutes)

Two control measurements were obtained, 15 minutes apart. At the completion of the second control period, the chamber door was closed and the vacuum lines were opened. Ascent was started at the appropriate time by closing the exhaust lines and sealing the door. Upon reaching peak altitude, the first of the five altitude measurements was taken. The remaining four measurements were taken at succeeding 15-minute intervals. After completion of the fifth altitude measurement (approximately 68 minutes after reaching peak altitude), descent to ground level was begun. The subject then rested at ground level for 30 minutes, after which a recovery measurement was taken.

Each measurement period, eight per exposure, took between 7 and 8 minutes and contained identical parameters. Venous blood (12-13 ml) was drawn into heparinized containers (Monoject, 10 ml tubes with Na^+ Heparin, and 3 ml syringe with Heparin coating; Heparin, Sodium injection, 1000 USP units/ml, Elkins-Sinn, Inc.). The blood was kept on ice and removed from the chamber periodically during the exposure using pass-through locks. Blood pressure was taken with a sphygmomanometer and stethoscope. Heart rate and respiration rate were taken from the ECG tracing (Physiograph, E & M Instrument Co., Inc. with coupler and amplifier by Narco Bio-Systems, Inc.) at a chart speed of 0.5 cm/minute and 0.1 cm/minute, respectively. The slower chart speed allowed respiratory movements to be counted. Respiration rate was also taken by observing and counting chest movements. The ECG and manually obtained respiration rates were averaged for each measurement period.

The psychological state and the degree of acute mountain sickness (AMS) in each subject was determined using a Visual Analogue Scale (VAS) (2,41) which contained 10 pairs of opposing adjectives (Fig. 2). This test was given to each subject during each of the measurement periods. The subjects indicated, by placing a mark on unmarked 100 mm lines between the opposing adjectives, what point best described their feelings. The distance from the left hand margin to the mark was measured. Five of the adjective pairs represented the most common early symptoms of AMS; nausea, lethargy, difficult breathing, muzziness, and headache (19,32). Five of the adjective pairs gave an index of psychological state; withdrawn, antagonistic, excited, troubled, and discontented (41). For each VAS parameter, data was analyzed as the difference from a control response, which was the average of the two control measurements. For example, during one exposure, a subject may have indicated a mild headache during the control periods, his marks were 3 mm from the left margin. During the first three altitude periods, this mark remained at 3 mm and so they were recorded as zero difference. By the fourth altitude period, the headache was worse and his mark was at the 6 mm point which gave him a difference from control of three.

Venous blood samples (2 ml) from the resting subjects were analyzed for P_{O2}, P_{CO2}, and pH (Radiometer-Copenhagen, pH meter 27) and for O_2 content ($LexO_2$ Con-K, Lexington Instruments, Corp., Walter, MA). The remaining blood (10-11 ml) was centrifuged for 10 minutes at 16,000 rpm at 5°C in a refrigerated centrifuge (Sorvall, Superspeed RC2-B). The plasma was placed in culture tubes in 2.5 ml

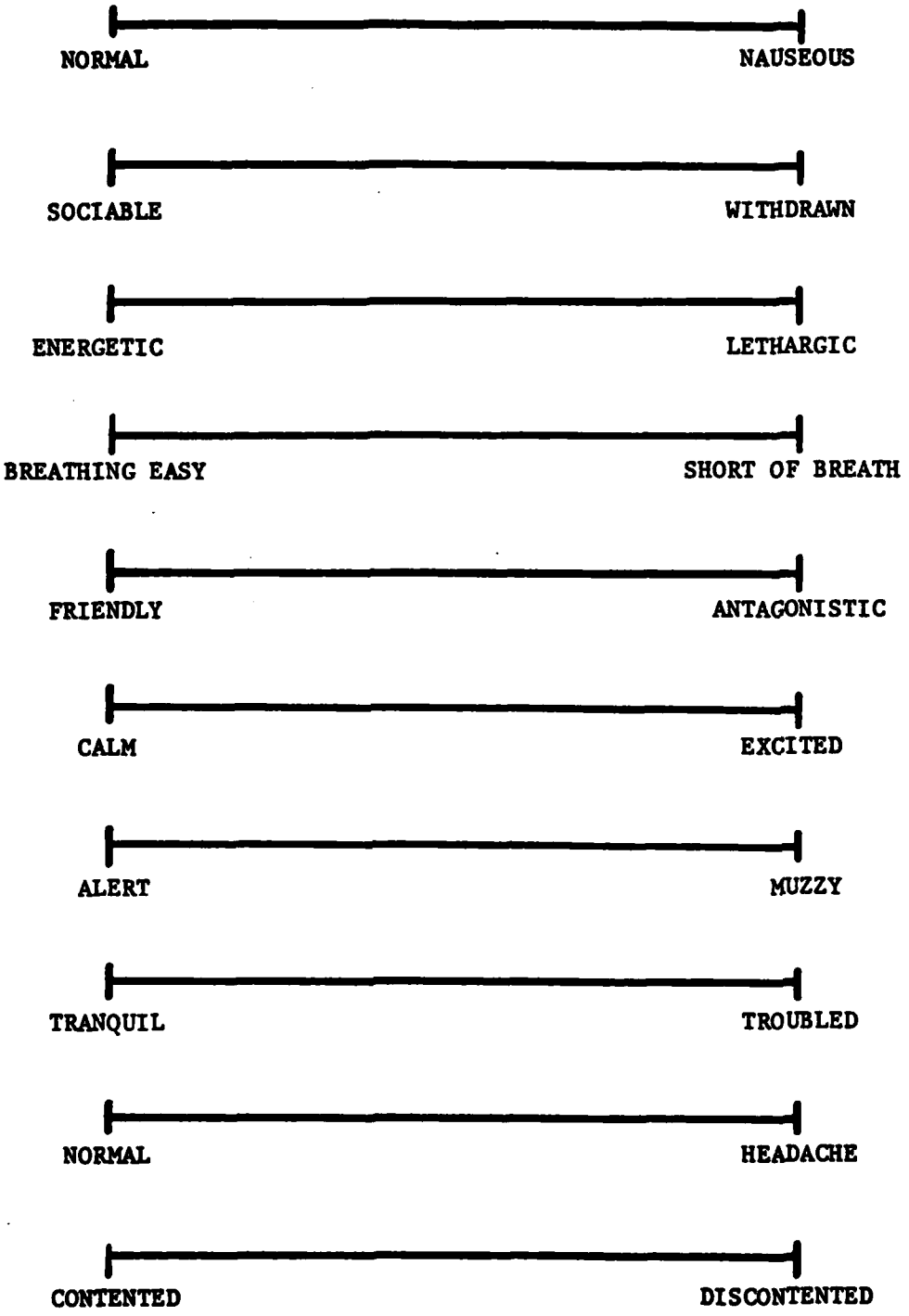


Figure 2. VAS Survey Sheet. Subject marked each uncalibrated 100 mm line to indicate how close he felt to either of the opposing adjectives.

aliquots and stored at -40°C until analyzed for catecholamines (about 3-6 weeks later).

Plasma catecholamines were analyzed by High Performance Liquid Chromatography with Electrochemical Detection (Bioanalytical Systems, BAS, chromatography column 5 g sodium octyl disulfate, LC-3 detector and RYT recorder) (4,21). Norepinephrine (NE) and epinephrine (E) were isolated using the preferential binding of amines to alumina oxide at a pH of 8.6. The alumina was washed and then the catecholamines were resuspended in 0.1 M perchloric acid and the supernatant injected into the chromatography unit. Using injections of known quantities of standard catecholamine solutions, recovery was approximately 75%.

Statistical analysis of the collected data was by two factor, repeated measures, analysis of variance with repeated measures in both factors. A significance level of 5% was established a priori. Where interaction between the two factors was statisticaly indicated, the data was further analyzed by Newman-Keuls post-hoc test for difference between pairs of means (43). Analysis of correlation between altitude vs catecholamine level and altitude vs AMS state was also carried out.

CHAPTER III

RESULTS

Catecholamines

Individual NE levels for all subjects are listed in Tables 2 through 7. The figure in the last column represents the pooled altitude measurements subtracted from the control value. The mean resting plasma NE level, obtained by averaging all of the control measurements, was 365 $\pm$ 20 pg/ml. During the 5,000 ft sham exposure, the plasma NE level (compressed across time) was 384 $\pm$ 18 pg/ml, indicating no change in NE release due to the exposure profile (Fig. 3A). During the 8,500 exposure, a significant increase in plasma NE levels occurred at the first, third, fourth, and fifth altitude measurements ($P \leq .05$), but not during the second measurement period. The NE level during the recovery period was also significantly higher ($P \leq .01$) than the control level (Fig. 3B). At 12,500 ft no significant change in plasma NE levels was seen (Fig. 3C). During the 17,000 ft exposure, the first altitude measurement exhibited a significant rise in NE, from a control value of 360 $\pm$ 27 pg/ml to 498 $\pm$ 67 pg/ml ($P \leq .01$). The subsequent two measurements were also elevated, 459 $\pm$ 43 pg/ml and 472 $\pm$ 73 pg/ml, respectively ($P \leq .05$). However, the fourth and fifth altitude NE levels appeared elevated (Fig. 3D) but were not significantly different from the control levels.

Table 2

RA's plasma NE levels
(pg/ml)

ALTITUDE OF EXPOSURE	MEASUREMENT PERIODS AT ALTITUDE							Δ
	CONTROL	1	2	3	4	5	RECOVERY	(ALT_p-C)
*5,000 ft	200	200	178	232	217	239	205	+13
*8,500 ft	243	187	171	203	187	233	223	-47
*12,500 ft	445	286	269	295	303	362	359	-142
17,000 ft	306	344	365	357	352	403	327	+58

*used heating pad.

Table 3

KG's plasma NE levels
(pg/ml)

ALTITUDE OF EXPOSURE	CONTROL	MEASUREMENT PERIODS AT ALTITUDE					RECOVERY	Δ (ALT_p-C)
		1	2	3	4	5		
5,000 ft	487	597	527	457	546	579	496	+54
8,500 ft	686	825	895	889	877	847	1056	+181
12,500 ft	609	559	628	567	587	559	585	-29
*17,000 ft	347	448	405	371	407	474	339	+74

*used heating pad.

Table 4

BR's plasma NE levels
(pg/ml)

ALTITUDE OF EXPOSURE	CONTROL	MEASUREMENT PERIODS AT ALTITUDE					RECOVERY	Δ (ALT_p-C)
		1	2	3	4	5		
5,000 ft	448	461	468	415	507	509	470	+24
8,500 ft	432	724	596	626	550	503	532	+168
12,500 ft	329	377	334	294	298	306	252	-7
17,000 ft	460	814	656	822	588	716	602	+259

Table 5

DR's plasma NE levels
(pg/ml)

ALTITUDE OF EXPOSURE	MEASUREMENT PERIODS AT ALTITUDE							Δ
	CONTROL	1	2	3	4	5	RECOVERY	$(ALT_p - C)$
5,000 ft	285	332	411	410	396	401	499	+105
8,500 ft	361	589	556	681	629	554	564	+241
12,500 ft	284	479	426	488	384	496	309	+171
17,000 ft	209	449	418	374	315	321	260	+166

Table 6

DS's plasma NE levels
(pg/ml)

ALTITUDE OF EXPOSURE	CONTROL	MEASUREMENT PERIODS AT ALTITUDE					RECOVERY	Δ (ALT_p-C)
		1	2	3	4	5		
5,000 ft	558	592	416	408	375	266	259	-147
8,500 ft	242	218	274	248	210	273	238	+3
12,500 ft	201	206	221	231	182	237	267	+14
17,000 ft	456	504	487	421	347	307	349	-43

Table 7

AT's plasma NE levels
(pg/ml)

ALTITUDE OF EXPOSURE	CONTROL	MEASUREMENT PERIODS AT ALTITUDE					RECOVERY	Δ (ALT_p-C)
		1	2	3	4	5		
5,000 ft	248	285	271	302	301	355	378	+55
8,500 ft	302	298	357	333	329	386	442	+39
12,500 ft	242	281	265	295	274	238	316	+29
17,000 ft	378	430	420	489	517	428	437	+79

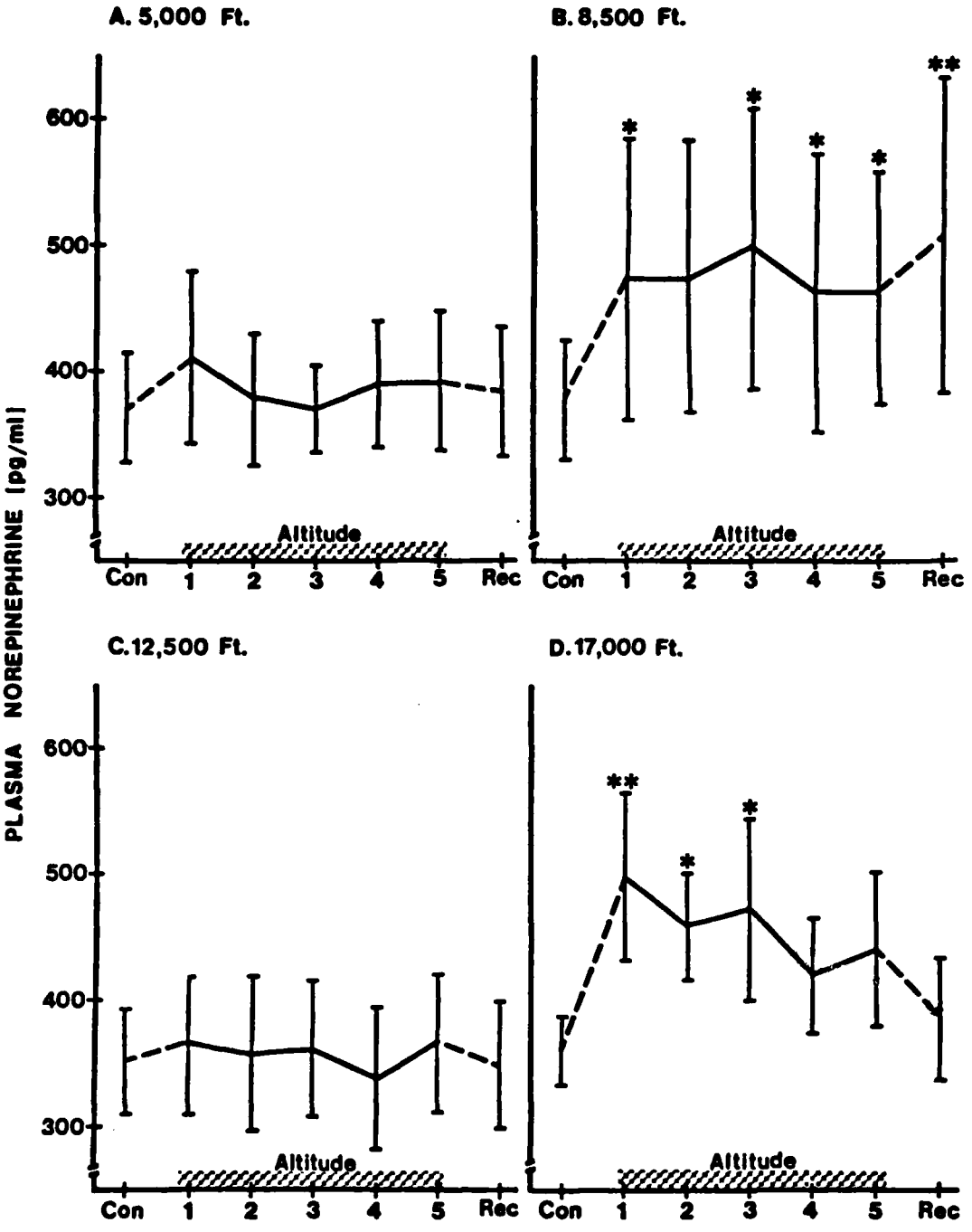


Figure 3. Mean plasma NE levels for each measurement period by altitude. Con = average of both control measurements. Rec = recovery measurement. Values marked with asterisk(s) are significantly different from Con (*P≤.05, **P≤.01). Values represent means ± SEM. n=6.

There were no significant changes in plasma E levels during any of the altitude exposures (Fig. 4). A small, though insignificant, rise in E levels was evident with exposure to 17,000 ft (Fig. 4D).

Acute Mountain Sickness/Psychological Survey

The subjects' own assessment of his level of AMS correlated well with altitude in four of the five symptoms assessed. Table 8 gives the mean values of all six subjects by altitude and measurement period. In response to whether they felt nauseous at each altitude, only on subject, DR, had a strong response (18.7 mm above his control rating), but only during the 17,000 ft exposure. This response peaked at the fourth altitude measurement. All other subjects indicated minimal or no sensation of nausea (<3.2 mm above control response) during the altitude exposures.

In response to whether the subjects felt energetic/lethargic (Fig. 5), there was no difference between the 8,500 ft and 5,000 ft exposures. One subject's data (KG) was discarded as an outlier in the 8,500 ft exposure. He had indicated a strong lethargic state during the control measurements and then became more energetic as the exposure proceeded (Appendix C). All of his data points were greater than two standard deviations from the mean. Since this subject was also very difficult to catheterize that morning, the effect was probably due to recovery from that trauma and not due to the altitude exposure. The exposure to 12,500 ft did elicit a significant response of greater lethargy than the sham exposure ($P \leq .01$). The 17,000 ft lethargic response was significantly greater than both the sham ($P \leq .01$) and the 8,500 and 12,500 ft exposures ($P \leq .01$).

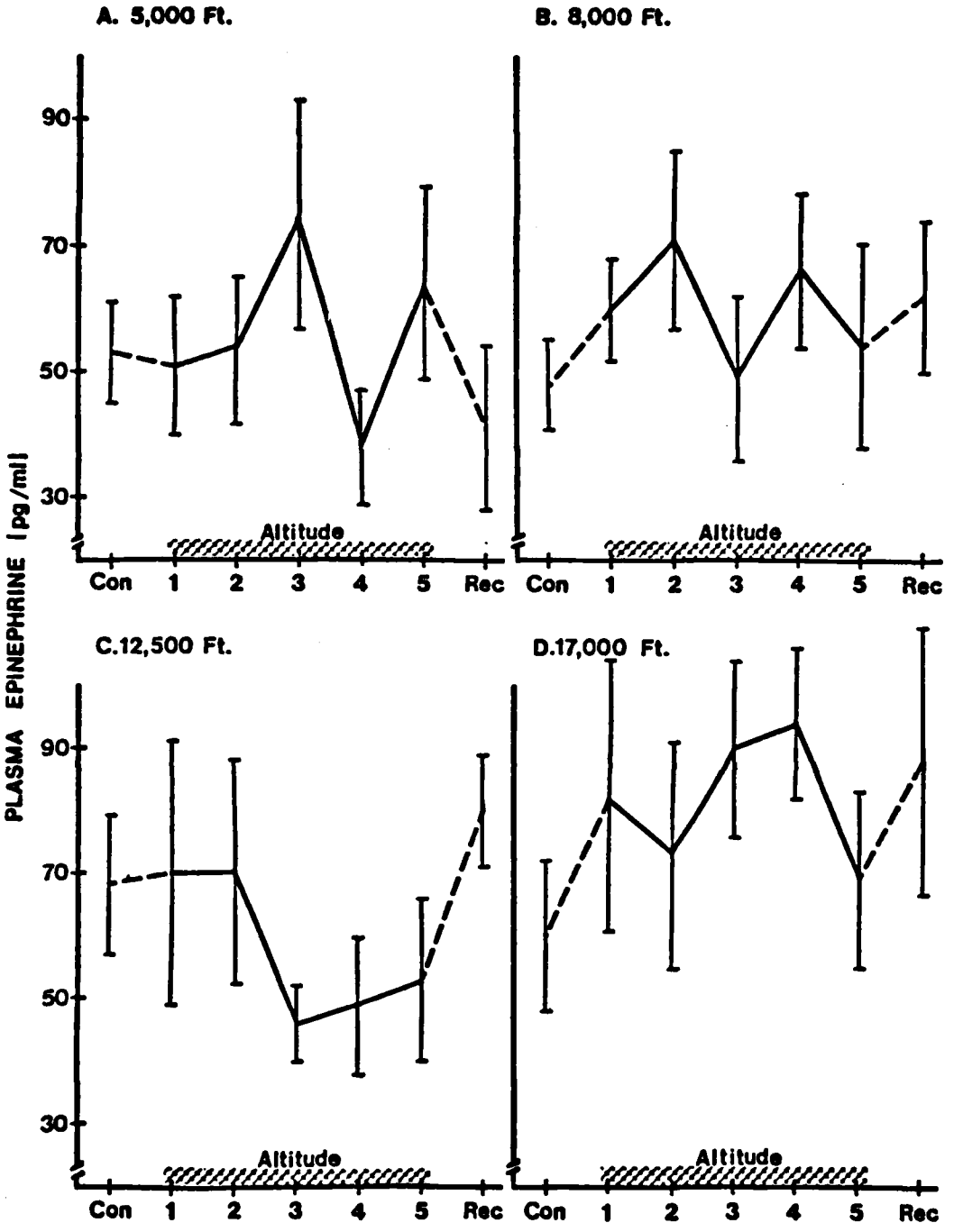


Figure 4. Mean plasma E levels for each measurement period by altitude. Con = average of both control measurements. Rec = recovery measurement. Values represent means ± SEM. n=6.

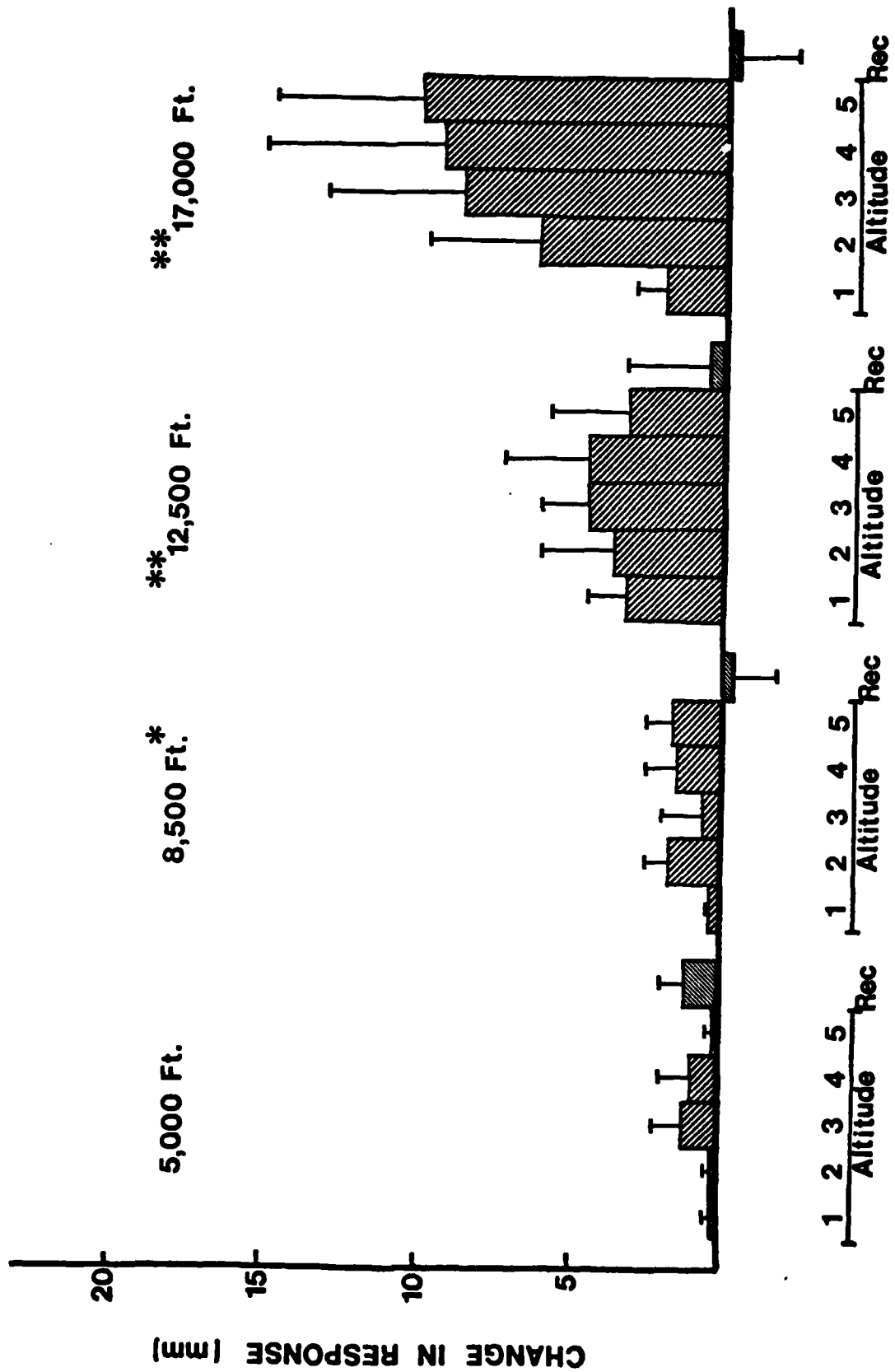
Table 8

Values for subjects' AMS responses expressed as the difference from the control. (mean ± SEM)

Factor	Altitude of Exposure 5,000 ft	8,500 ft	12,500 ft	17,000 ft
NAUSEOUS				
Alt-1	0.3 ± 0.3	0.4 ± 0.6	0.4 ± 0.6	-0.1 ± 0.2
Alt-2	-0.2 ± 0.5	0.6 ± 0.3	0.2 ± 0.3	1.2 ± 1.4
Alt-3	0.3 ± 0.3	0.9 ± 0.5	0.2 ± 0.3	2.2 ± 2.1
Alt-4	0.3 ± 0.4	0.3 ± 0.2	0.2 ± 0.4	3.5 ± 3.1
Alt-5	0.3 ± 0.4	0.4 ± 0.6	0.5 ± 0.6	2.6 ± 2.0
Rec	0.4 ± 0.3	0.3 ± 0.4	-0.1 ± 0.3	-0.4 ± 0.2
LETHARGIC				
Alt-1	0.4 ± 0.3	*0.3 ± 0.3	3.2 ± 1.3	2.1 ± 1.0
Alt-2	0.4 ± 0.3	*1.7 ± 0.8	3.8 ± 2.3	6.3 ± 3.5
Alt-3	1.4 ± 1.0	*0.7 ± 1.3	4.5 ± 1.5	8.7 ± 4.3
Alt-4	1.0 ± 1.0	*1.6 ± 1.0	4.6 ± 2.8	9.2 ± 5.8
Alt-5	0.4 ± 0.1	*1.7 ± 1.0	3.3 ± 2.5	10.1 ± 4.8
Rec	1.3 ± 0.8	*0.3 ± 1.5	0.5 ± 2.8	-0.2 ± 2.0
BREATHING EASY				
Alt-1	0.0 ± 0.3	1.3 ± 0.5	3.4 ± 2.5	5.1 ± 1.5
Alt-2	0.0 ± 0.2	1.0 ± 0.7	4.6 ± 3.5	5.2 ± 3.0
Alt-3	-0.1 ± 0.3	1.1 ± 0.5	5.2 ± 4.2	7.0 ± 3.3
Alt-4	-0.3 ± 0.3	1.2 ± 0.8	2.8 ± 2.9	6.5 ± 3.0
Alt-5	-0.1 ± 0.2	0.7 ± 0.5	1.2 ± 1.9	5.2 ± 2.3
Rec	0.3 ± 0.2	0.2 ± 0.5	-0.4 ± 0.3	0.3 ± 0.3
MUZZY				
Alt-1	-0.3 ± 0.5	1.0 ± 0.8	2.0 ± 1.5	1.2 ± 1.4
Alt-2	0.5 ± 0.5	2.5 ± 1.4	5.5 ± 2.8	5.5 ± 4.0
Alt-3	0.3 ± 1.2	0.7 ± 0.5	7.6 ± 4.0	10.7 ± 5.0
Alt-4	0.2 ± 1.0	0.9 ± 1.4	5.4 ± 3.5	10.1 ± 6.3
Alt-5	-0.3 ± 0.5	1.8 ± 1.0	4.4 ± 4.0	17.0 ± 5.8
Rec	-1.4 ± 0.8	1.3 ± 1.0	0.2 ± 1.2	0.1 ± 0.2
HEADACHE				
Alt-1	-0.3 ± 0.3	1.3 ± 0.8	0.8 ± 0.8	2.1 ± 1.0
Alt-2	0.5 ± 0.5	0.7 ± 0.5	5.3 ± 4.3	5.5 ± 3.8
Alt-3	0.2 ± 0.3	-0.1 ± 0.5	4.7 ± 2.5	8.4 ± 5.8
Alt-4	0.5 ± 0.7	0.0 ± 0.5	3.1 ± 1.5	8.2 ± 4.5
Alt-5	0.0 ± 0.5	-0.4 ± 0.5	1.8 ± 1.0	15.4 ± 8.0
Rec	0.0 ± 0.4	-0.3 ± 0.4	1.6 ± 0.8	2.8 ± 1.5

* without KG's data

Figure 5. Mean VAS response to feelings of lethargy for each measurement period by altitude. Expressed as the difference from the mean control indication. Rec = recovery measurement. * Data from KG were treated as outliers and removed. ** Significantly greater response seen during the altitude periods during the 12,500 and 17,000 ft exposures than seen during the 5,000 ft sham exposure, $p \leq .01$. n=6 (except *8,500 ft, n=5).


CHANGE IN RESPONSE (mm)
20
15
10
5
5,000 Ft.
8,500 Ft.*
**12,500 Ft.
**17,000 Ft.
1 2 3 4 5 Rec
Altitude

The subjects also indicated a decrease in ease of breathing with an increase in altitude. Though there was no significant difference between the 5,000 ft sham and the 8,500 ft responses, the subjects generally indicated more difficulty in breathing at the higher altitude (Fig. 6). Both the 12,500 ft. and the 17,000 ft exposure responses were significantly greater than the sham ($P \leq .01$) and were also significantly different from each other ($P \leq .01$) with the subjects indicating the greatest difficulty in breathing during the 17,000 ft exposures (Fig. 6).

In response to the alert/muzzy classification (Fig. 7), the subjects felt only slightly more muzzy during the 8,500 ft exposures, but this was not significant. They were significantly more muzzy at 12,500 and 17,000 ft ($P \leq .01$) and again the 17,000 ft response was significantly greater than the 12,500 ft response ($P \leq .01$).

Finally, in response to whether the exposure to altitude caused a headache, there was no difference between the 5,000 ft sham and the 8,500 ft exposure. Exposure to 12,500 ft produced a significant headache response ($P \leq .05$) with a peak at the second measurement period (Fig. 8) and then a decline toward the control level. Exposure to 17,000 ft produced a very strong response ($P \leq .01$). The peak response here, a change of $+15.4 \pm 7.9$ mm, did not occur until the fifth measurement at altitude. In summary, exposure to 8,500 ft did not elicit any significant symptoms of AMS, whereas 12,500 and 17,000 ft did, with the strongest subjective response to all five symptoms occurring at 17,000 ft.

Of the five psychological stress indices chosen (sociable/withdrawn, friendly/antagonistic, calm/excited, tranquil/troubled, and

Figure 6. Mean VAS response to feelings of shortness of breath for each measurement period by altitude. Expressed as the difference from the mean control indication. Rec = recovery measurement. ** Significantly greater response seen during the altitude periods during the 12,500 and 17,000 ft exposures than seen during the 5,000 ft sham exposure, $p \leq .01$. n=6.

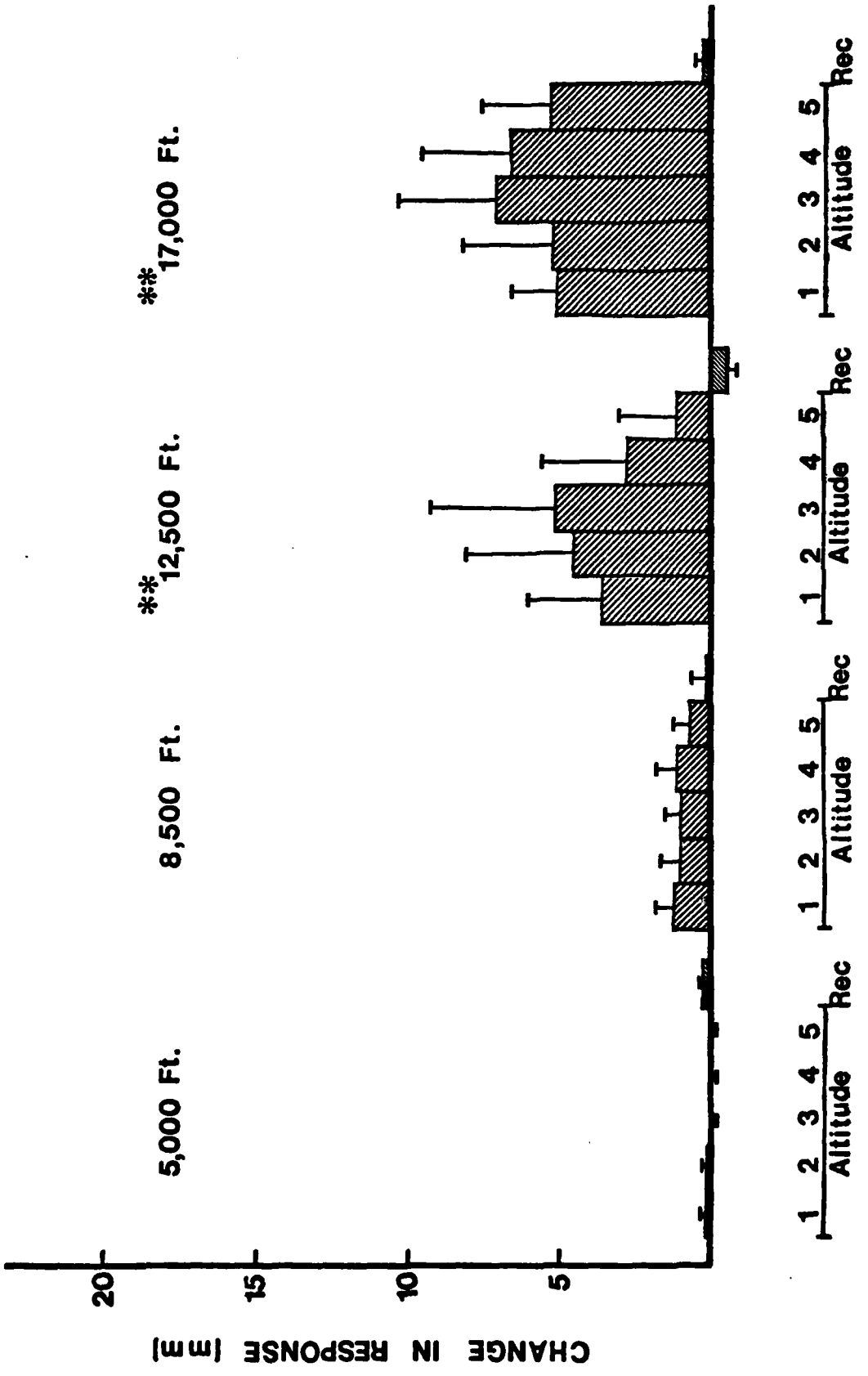

CHANGE IN RESPONSE [mm]
20
15
10
5
5,000 Ft.
8,500 Ft.
**12,500 Ft.
**17,000 Ft.
1 2 3 4 5 Rec
Altitude

Figure 7. Mean VAS response to feelings of muzziness for each measurement period by altitude. Expressed as the difference from the mean control indication. Rec = recovery measurement. ** Significantly greater response seen during the altitude periods during the 12,500 and 17,000 ft exposures than seen during the 5,000 ft sham exposure, $p \leq .01$. n=6.

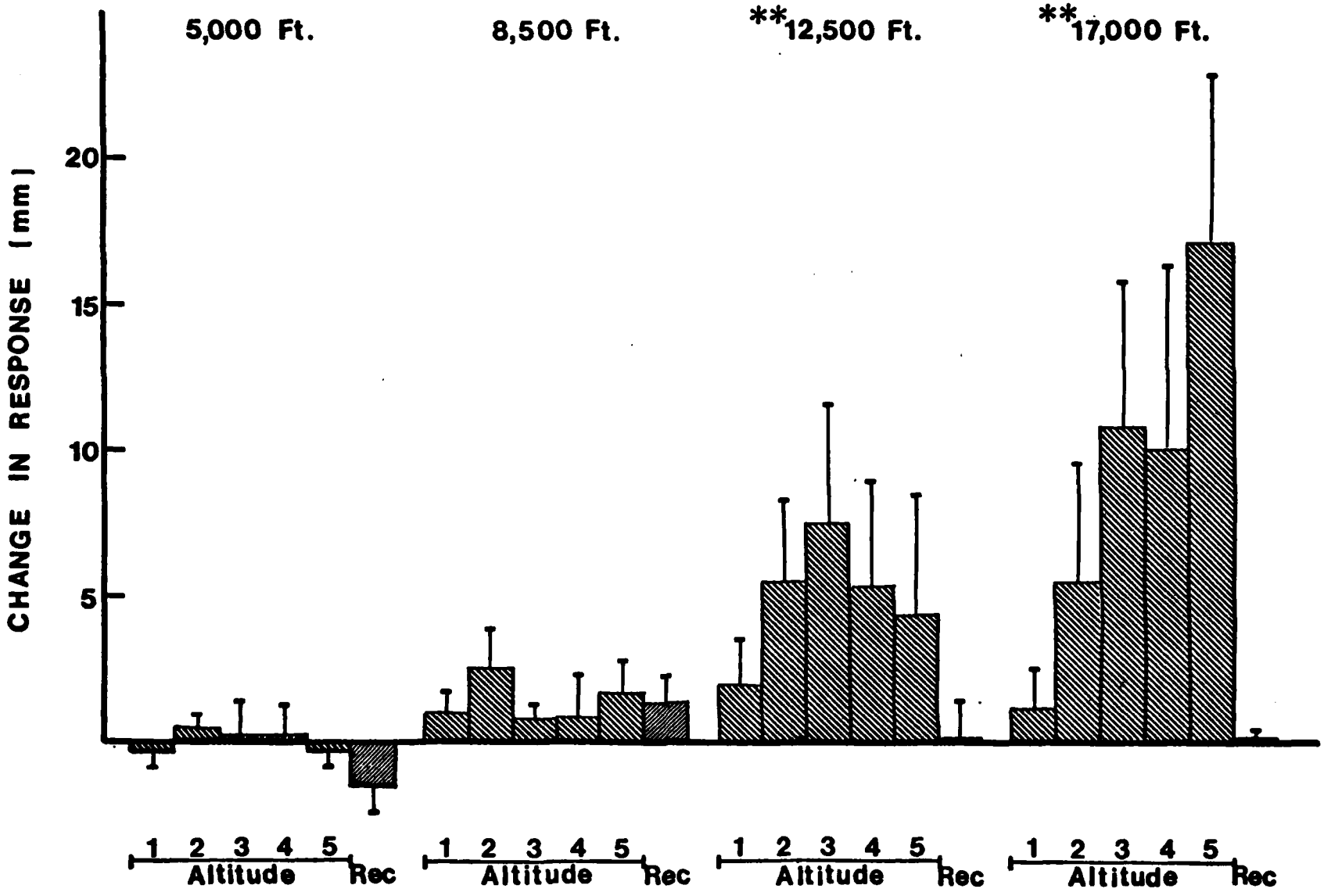
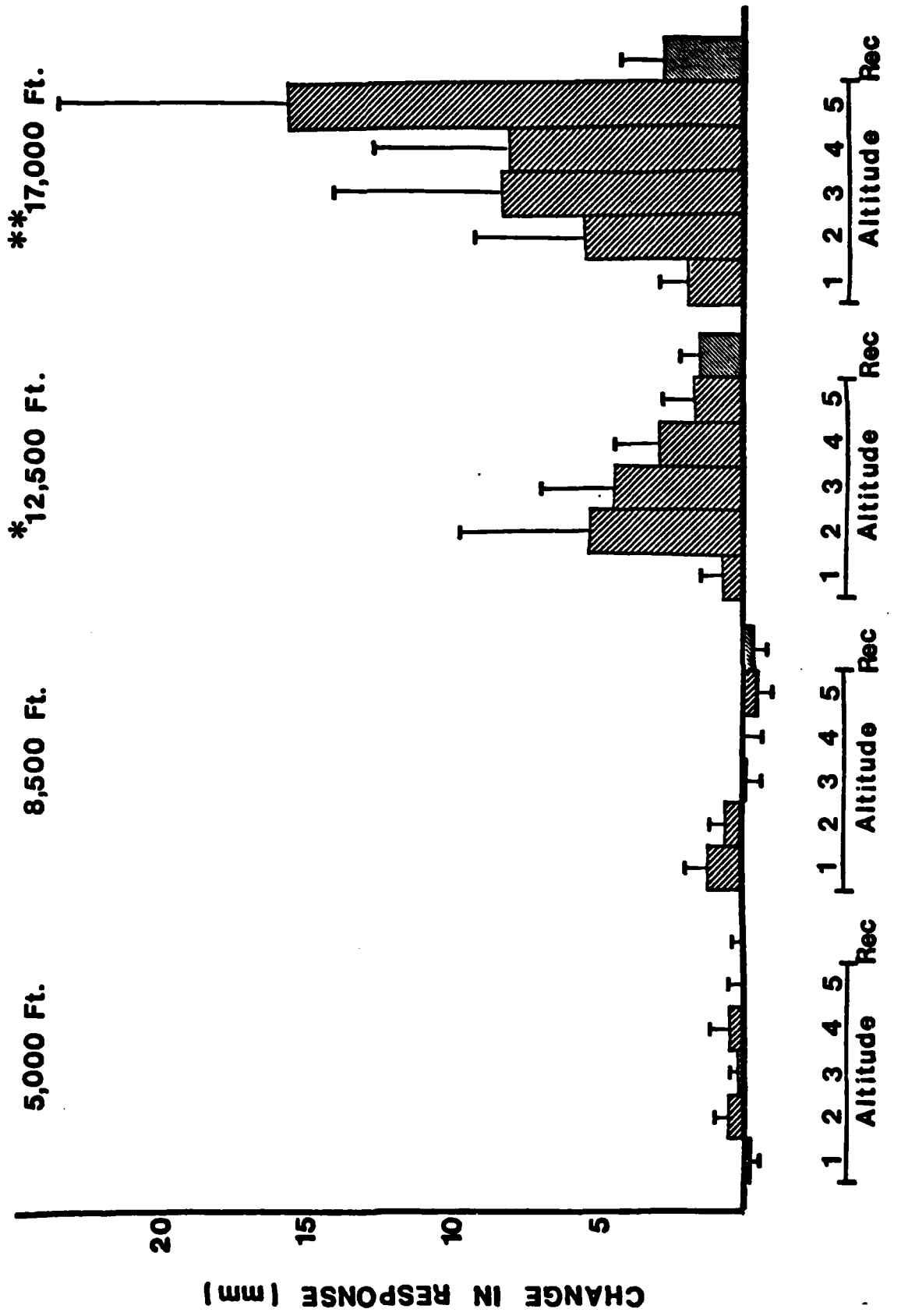

5,000 Ft.
8,500 Ft.
**12,500 Ft.
**17,000 Ft.
CHANGE IN RESPONSE (mm)
20
15
10
5
1 2 3 4 5
Altitude
Rec
1 2 3 4 5
Altitude
Rec
1 2 3 4 5
Altitude
Rec
1 2 3 4 5
Altitude
Rec

Figure 8. Mean VAS response to feelings of a headache for each measurement period by altitude. Expressed as the difference from the mean control indication. Rec = recovery measurement. * Significantly greater response seen during the altitude periods during the 12,500 ft exposure than seen during the 5,000 ft sham exposure, $p \leq .05$. ** Significantly greater response seen during the altitude periods during the 17,000 ft exposure than seen during the 5,000 ft sham exposure, $p \leq .01$. n=6.


CHANGE IN RESPONSE (mm)
20
15
10
5
5,000 Ft.
8,500 Ft.
*12,500 Ft.
**17,000 Ft.
1 2 3 4 5 Rec
Altitude

contented/discontented), none exhibited a significant change in response due to the altitude exposures (Table 9).

Oxygen Content and PO_2

Venous oxygen content and PO_2 both showed the same pattern of change during the exposure and were well correlated ($r=.95$, $P \leq .01$). Therefore, only the oxygen content data will be reported since some PO_2 data was not collected. Venous blood oxygen levels tended to decline with time during the 5,000 ft sham exposure (Fig. 9A). Oxygen content fell from 10.8 ± 0.8 vol% during the control period to 8.6 ± 1.3 vol% during the recovery period, although this drop was not statistically significant. Upon reaching 8,500 ft, there was an appreciable, though not significant, drop in oxygen content from 9.1 ± 1.0 to 6.6 ± 0.9 vol%. However, a similar drop was not seen during the 12,500 ft exposure (Figs. 9B and 9C). The 17,000 ft exposure did produce a distinct and significant drop in O_2 content ($P \leq .01$) from a control level of 9.9 ± 1.1 vol% to 6.3 ± 0.9 vol% at the first altitude measurement (Fig. 9D).

Venous PCO_2

Neither the 5,000 nor the 8,500 ft exposures produced any change in venous PCO_2 (Figs. 10A and 10B). At 12,500 ft, a significant drop in PCO_2 occurred by the second altitude period ($P \leq .01$), falling from a control of 53.7 ± 1.5 torr to 43.3 ± 2.3 torr (Fig. 10C). A similar fall occurred during the 17,000 ft exposure from a control of 53.5 ± 1.8 to 50.7 ± 2.4 torr ($P \leq .05$), but during this exposure, PCO_2 continued to fall until the fifth measurement period when it reached a low of 47.7 ± 3.3 torr (Fig. 10D).

Table 9

Values for subjects' psychological stress responses expressed as the difference from the control. (mean ± SEM)

Factor	Altitude of Exposure 5,000 ft	8,500 ft	12,500 ft	17,000 ft
CONTENTED				
Alt-1	0.1 ± 0.5	-0.3 ± 0.4	0.6 ± 0.4	1.2 ± 1.3
Alt-2	0.0 ± 0.3	1.1 ± 0.6	1.4 ± 0.8	3.7 ± 2.3
Alt-3	-0.1 ± 0.3	1.1 ± 1.0	0.8 ± 0.6	2.3 ± 1.7
Alt-4	-0.7 ± 0.5	1.5 ± 1.4	0.1 ± 0.5	3.2 ± 2.7
Alt-5	-0.4 ± 0.7	1.2 ± 1.2	-1.0 ± 0.5	1.7 ± 1.6
Rec	-0.5 ± 0.3	-1.0 ± 0.4	-0.1 ± 0.4	0.7 ± 0.9
SOCIABLE				
Alt-1	-0.2 ± 0.4	-2.1 ± 1.8	0.6 ± 0.3	0.4 ± 0.4
Alt-2	0.5 ± 0.7	-1.1 ± 2.4	-0.2 ± 0.4	3.1 ± 1.6
Alt-3	0.6 ± 0.6	-1.6 ± 2.6	1.0 ± 0.6	2.9 ± 2.4
Alt-4	-0.4 ± 0.4	-2.1 ± 2.6	1.0 ± 1.0	2.5 ± 1.7
Alt-5	-0.3 ± 0.2	-2.2 ± 2.8	-0.4 ± 0.6	1.2 ± 1.6
Rec	0.8 ± 0.3	-2.6 ± 2.9	0.1 ± 0.8	-0.3 ± 0.3
TRANQUIL				
Alt-1	1.7 ± 2.1	0.7 ± 1.0	-1.0 ± 0.6	1.0 ± 1.1
Alt-2	0.6 ± 0.8	1.4 ± 0.9	-2.0 ± 1.2	2.6 ± 1.7
Alt-3	0.6 ± 1.0	0.4 ± 1.0	-0.1 ± 0.8	4.0 ± 2.2
Alt-4	0.3 ± 0.8	1.8 ± 1.3	-1.0 ± 0.6	3.6 ± 3.2
Alt-5	0.5 ± 0.7	1.4 ± 1.2	-2.2 ± 1.3	2.4 ± 2.1
Rec	0.3 + 0.6	0.7 + 1.0	-1.7 + 1.0	0.4 + 0.3
CALM				
Alt-1	-0.8 ± 0.3	0.1 ± 0.6	-1.0 ± 1.7	0.7 ± 0.4
Alt-2	-0.8 ± 0.5	0.7 ± 0.4	0.7 ± 3.1	0.9 ± 1.2
Alt-3	-0.3 ± 0.5	0.2 ± 0.4	-0.9 ± 1.9	2.6 ± 1.2
Alt-4	-0.2 ± 0.5	0.0 ± 0.5	-1.5 ± 1.9	0.4 ± 0.5
Alt-5	-1.1 ± 0.6	0.4 ± 0.3	-0.8 ± 2.4	1.1 ± 1.2
Rec	-0.6 ± 0.4	0.1 ± 0.4	-1.4 ± 2.2	-0.8 ± 0.6
FRIENDLY				
Alt-1	0.8 ± 1.2	0.1 ± 0.5	0.2 ± 0.6	0.6 ± 0.9
Alt-2	-0.4 ± 0.1	1.6 ± 1.1	2.1 ± 2.1	0.6 ± 0.7
Alt-3	0.5 ± 0.6	1.0 ± 0.6	1.2 ± 0.6	1.9 ± 0.9
Alt-4	0.2 ± 0.4	1.3 ± 1.0	1.4 ± 0.5	0.3 ± 0.3
Alt-5	-1.1 ± 0.5	0.7 ± 0.7	0.2 ± 0.7	1.5 ± 0.8
Rec	-0.4 ± 0.2	0.0 ± 0.2	0.7 ± 0.6	-0.3 ± 0.6

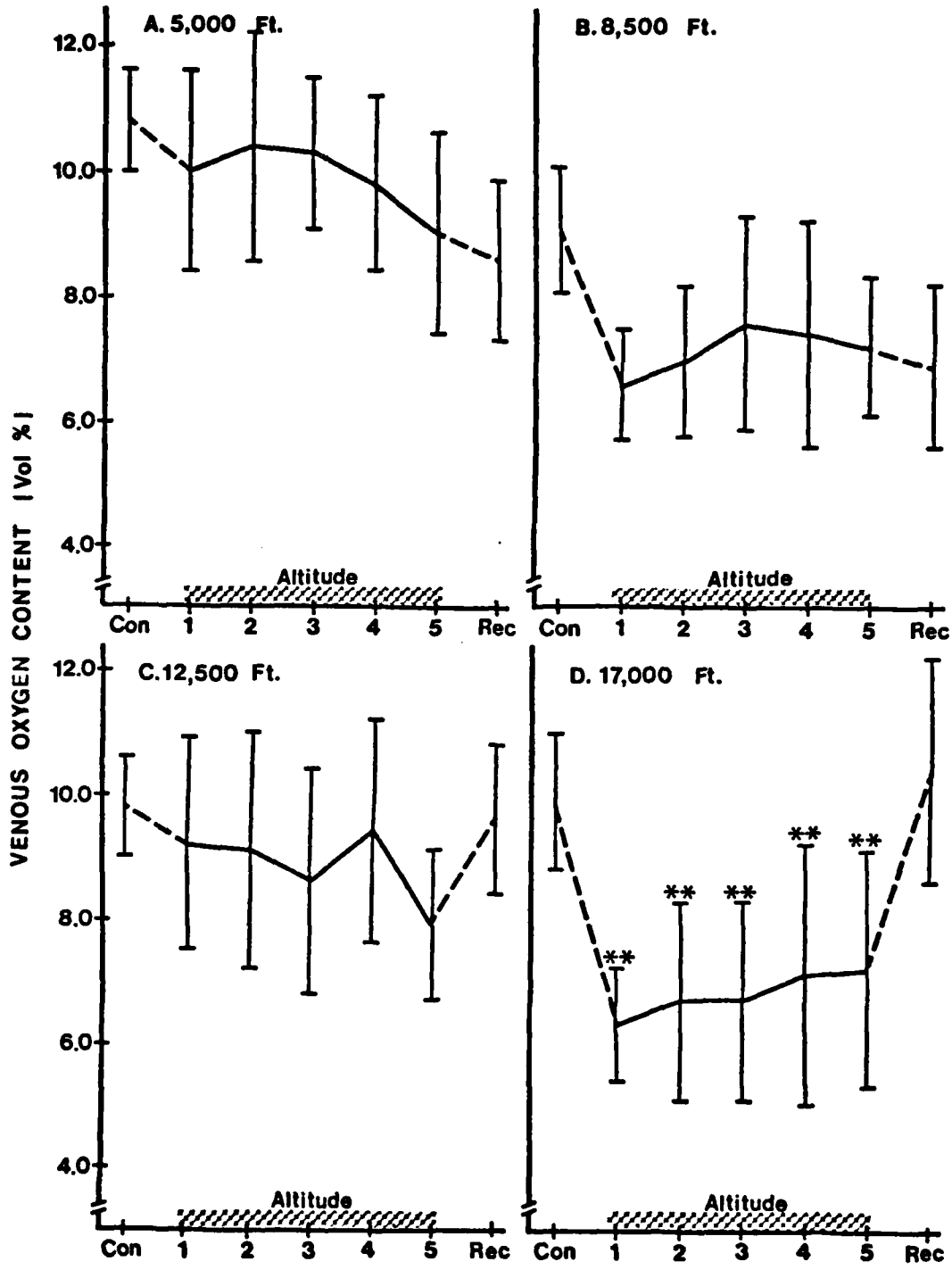


Figure 9. Mean venous oxygen content for each measurement period by altitude. Con = average of both control measurements. Rec = recovery measurement. Values marked with asterisks are significantly different from Con, $P \leq .01$. Values represent means $\pm$ SEM. n=6.

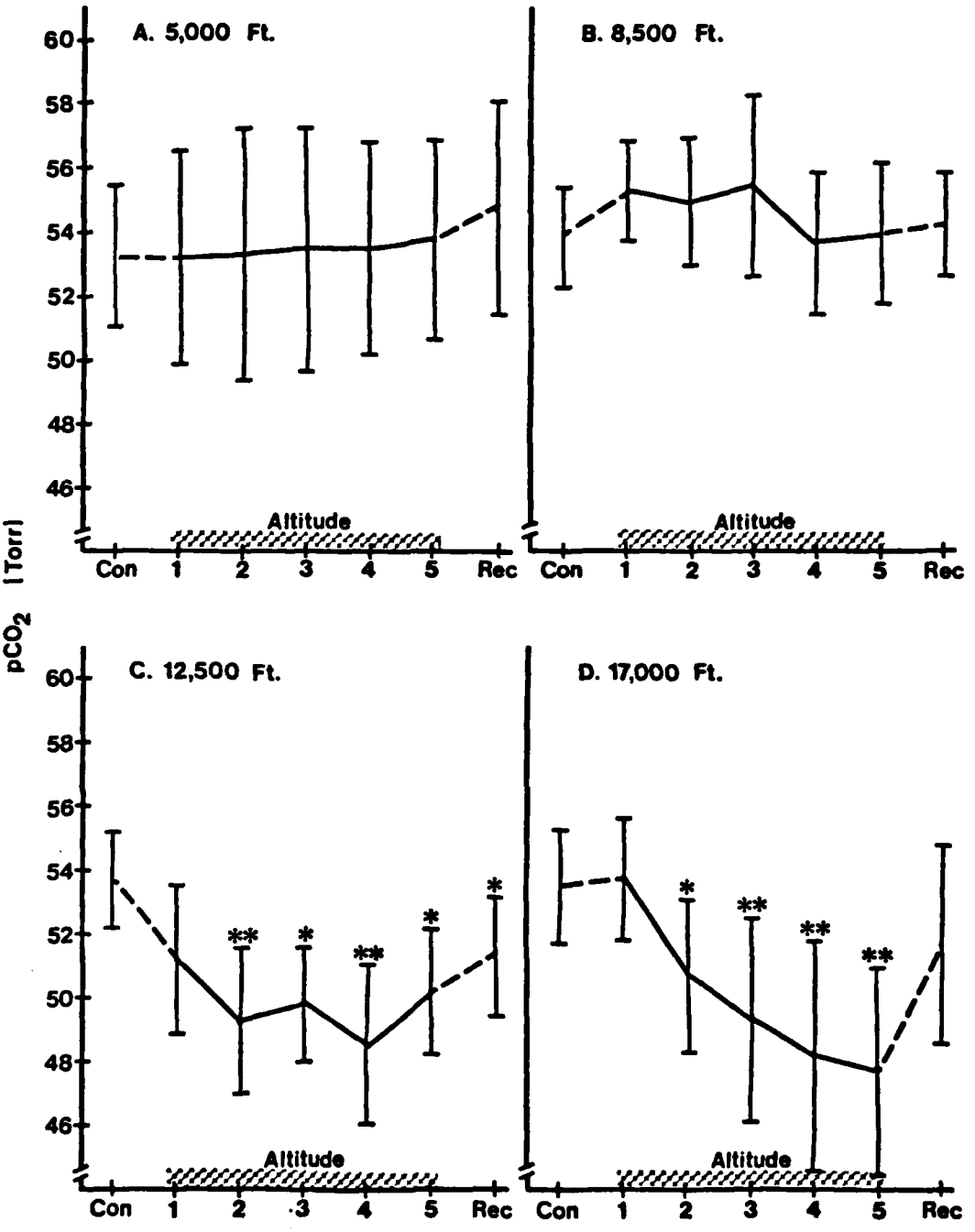


Figure 10. Mean venous P_{CO2} for each measurement period by altitude. Con = average of both control measurements. Rec = recovery measurement. Values marked with asterisk(s) are significantly different from Con (*$P \leq .05$, **$P \leq .01$). Values represent means $\pm$ SEM. n=6.

Venous pH

Venous pH did not change significantly during the sham 5,000 ft exposure. The control measurements during the 8,500 ft exposure were considerably lower than the control values during the 5,000 ft exposure (7.33 $\pm$ .01 vs 7.35 $\pm$ .01). Subsequently, the exposure to 8,500 ft did not induce a change in pH from its already low control level, but when compressed across time, the 8,500 ft exposure did produce a significantly lower pH compared to the 5,000 ft exposure ($P \leq .01$) (Figs. 11A and 11B). During the 12,500 ft exposure, pH rose from 7.34 $\pm$ .01 to 7.36 $\pm$ .01 by the first altitude measurement ($P \leq .01$). This increase continued until the fourth measurement period, then dropped slightly (Fig. 11C). pH during the recovery period was significantly higher (7.37 $\pm$ .01) than the control ($P \leq .01$). The exposure to 17,000 ft did not produce as immediate a response, but by the second altitude measurement, pH had risen to 7.38 $\pm$ .01 compared to the control value of 7.36 $\pm$ .004 ($P \leq .05$). The pH during the recovery period following the 17,000 ft exposure returned to control levels.

Respiratory Rate

No consistent change in respiratory rate occurred during any of the altitude exposures (Appendix M). Since tidal volume was not measured no inferences can be made as to changes in minute ventilation.

Blood Pressure

Mean blood pressure changes were variable and inconsistent in all cases but one (Appendix N). In subject DR, there was a distinct drop in blood pressure (from a control mean blood pressure of 84 to 71

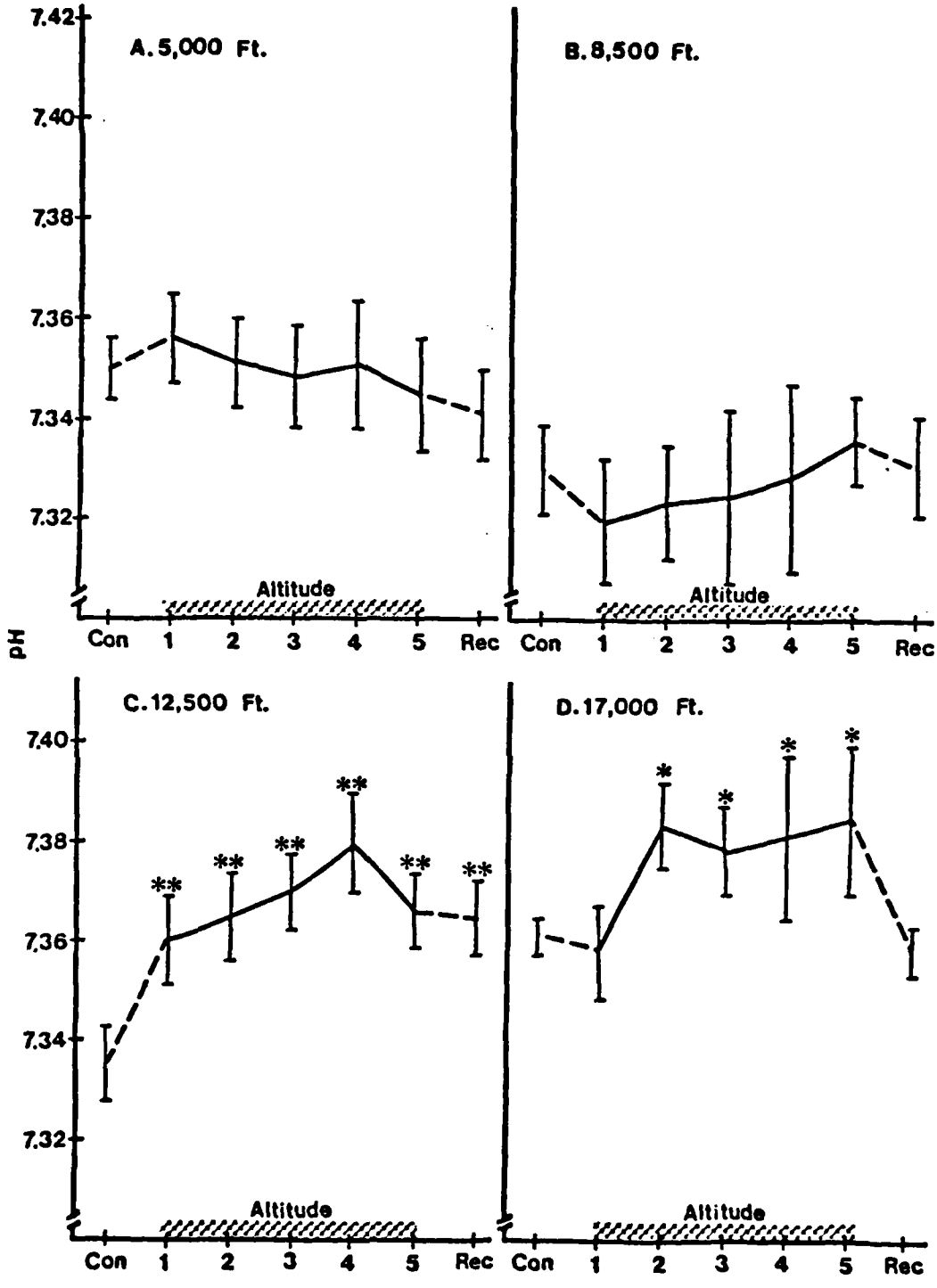


Figure 11. Mean venous pH for each measurement period by altitude. Con = average of both control measurements. Rec = recovery measurement. Values marked with asterisk(s) are significantly different from Con (*P≤.05, **P≤.01). Values represent means ± SEM. n=6.

torr) during his 17,000 ft exposure, with the lowest blood pressure occurring at the third altitude measurement. This closely followed the subjective report of nausea at this altitude for this subject.

Heart Rate

An apparent, but not significant, decrease in heart rate occurred with time during the 5,000 ft and 8,500 ft exposures (Figs. 12A and 12B). This reduction was not observed during the 12,500 ft exposure (Fig. 12C), and a significant rise occurred from a control of 62 $\pm$ 3 beats/minute to 71 $\pm$ 3 beats/minute during the first altitude measurements at 17,000 ft ($P \leq .01$). Thereafter, heart rate remained elevated at 17,000 ft. Heart rate fell significantly ($P \leq .05$) to below the control level (58 $\pm$ 3 beats/minute) during the ground level recovery period (Fig. 12).

Analysis of the data revealed two trends. Figure 13 represents the plasma NE value vs oxygen content for each measurement period at 5,000 ft. If all data are used, the heavy line is representative with an r value of 0.41. The points circled represent one subject and, though there is no clear reason to discount these points, they are considerably outside the distribution of the other subjects. If they are removed from the data, the thinner line best represents the distribution with an r value of 0.82. Figure 14 is the same representation for the 8,500 ft exposures with an r value of 0.66. At these two lower altitudes, an inverse relationship between venous NE and oxygen content seems to exist. No such correlation was observed for the 12,500 ft and 17,000 ft exposures.

The second trend which seemed to be present was a subdivision of the subjects into two groups based on thermal discomfort. The

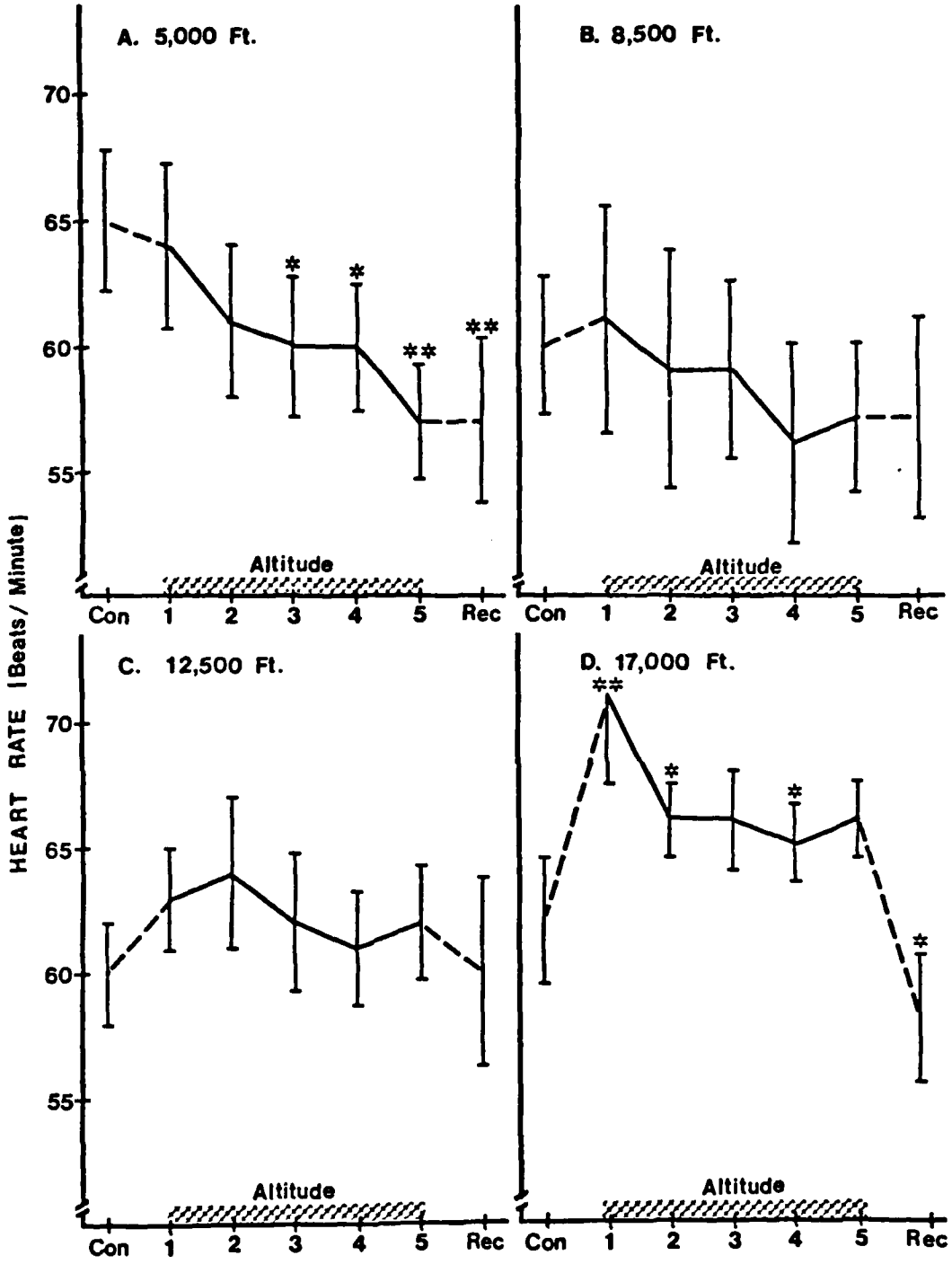


Figure 12. Mean heart rate for each measurement period by altitude. Con = average of both control measurements. Rec = recovery measurement. Values marked with asterisk(s) are significantly different from Con (*P≤.05, **P≤.01). Values represent means ± SEM. n=6.

Figure 13. Plasma NE level vs oxygen content for each measurement period at 5,000 ft. Heavy line represents data from all six subjects (r = 0.41). Circled data points represent one subject, DS. *Slope and correlation (r = 0.82) of data with DS points removed.

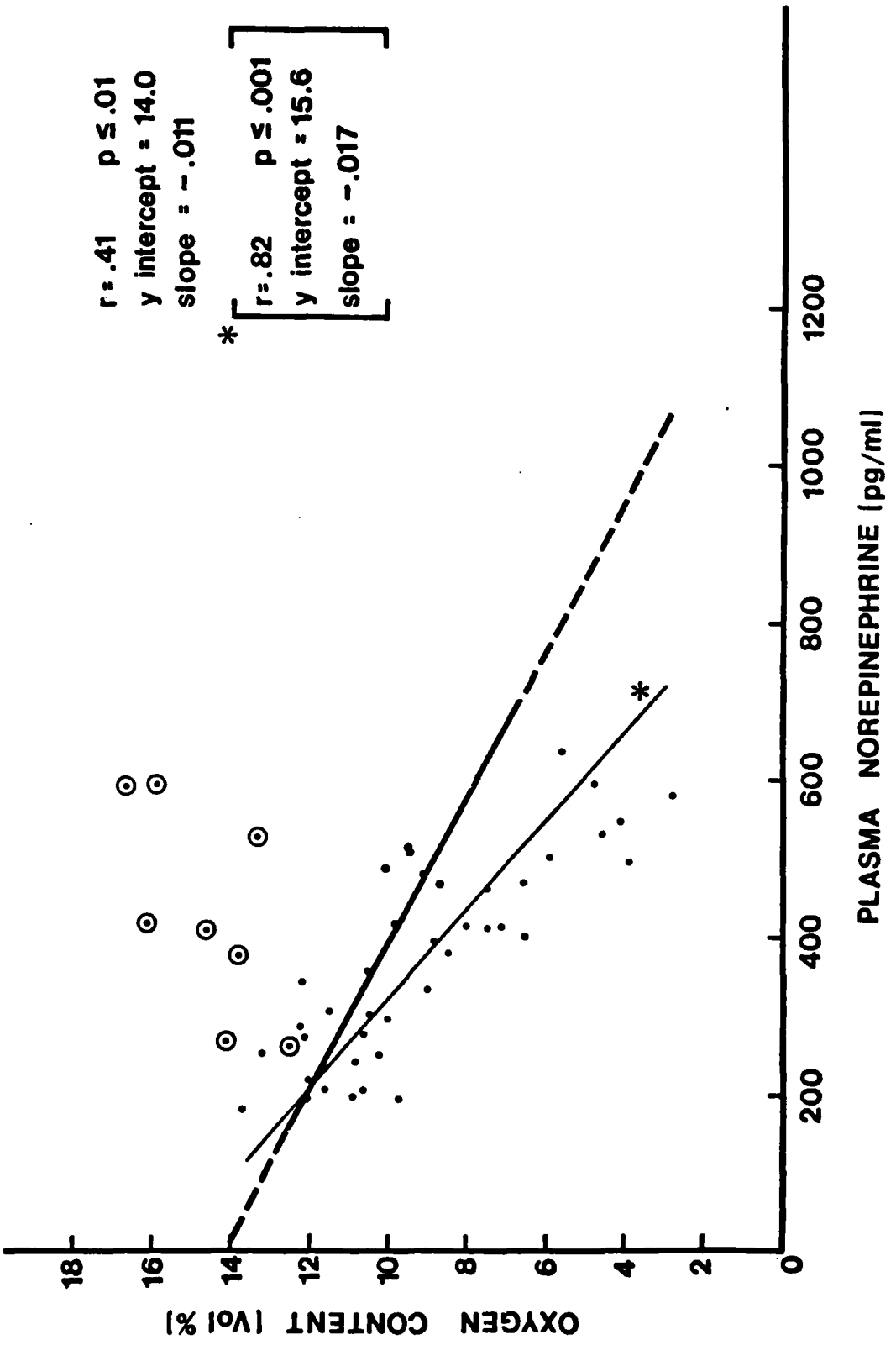
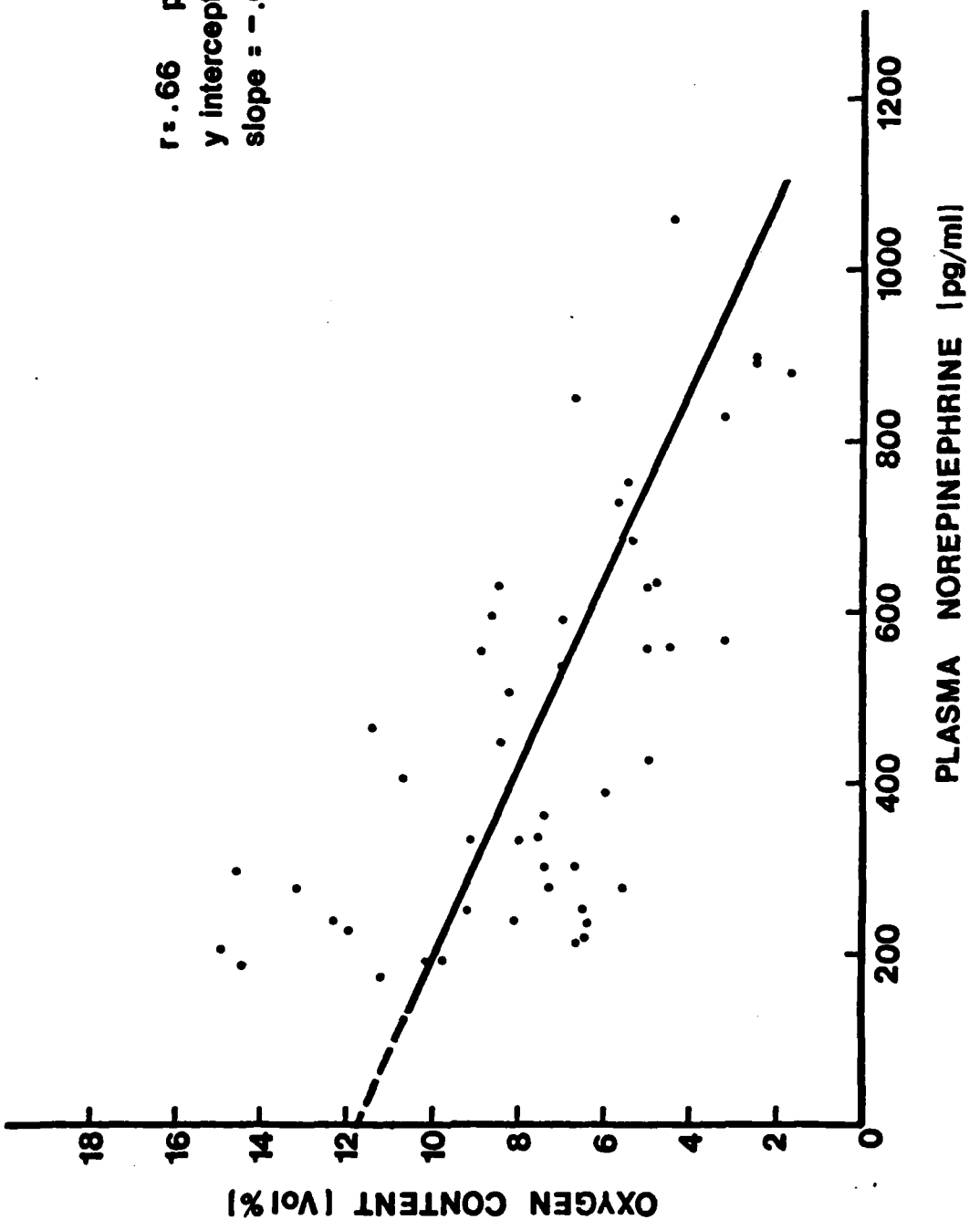

r = .41 p ≤ .01
y intercept = 14.0
slope = −.011
* [r = .82 p ≤ .001
y intercept = 15.6
slope = −.017]
OXYGEN CONTENT (Vol %)
18
16
14
12
10
8
6
4
2
0
200
400
600
800
1000
1200
PLASMA NOREPINEPHRINE (pg/ml)

Figure 14. Plasma NE level vs oxygen content for each measurement period at 8,500 ft. Each dot represents one subject at one measurement period. All six subjects are represented. ($r = 0.66$).


r=.66 p≤.001
y intercept = 11.8
slope = -.009
OXYGEN CONTENT [Vol %]
PLASMA NOREPINEPHRINE [pg/ml]
0
200
400
600
800
1000
1200
2
4
6
8
10
12
14
16
18

subjects who felt subjectively colder had distinct chilling of the hands during all exposures or did not use a heating pad. The other three subjects either did not feel as cold or used a heating pad during the experiment. Analysis of the data, when grouped in this way, showed a marked difference in plasma NE levels between the two groups at the three lower altitude exposures; the cold responders showed a marked increase in plasma NE levels, while the warmer subjects showed minimal responses (Figs. 15A, 15B, and 15C). During the 17,000 ft exposure, both groups showed a marked increase in plasma NE level, with the colder subjects still exhibiting the greater response (Fig. 15D).

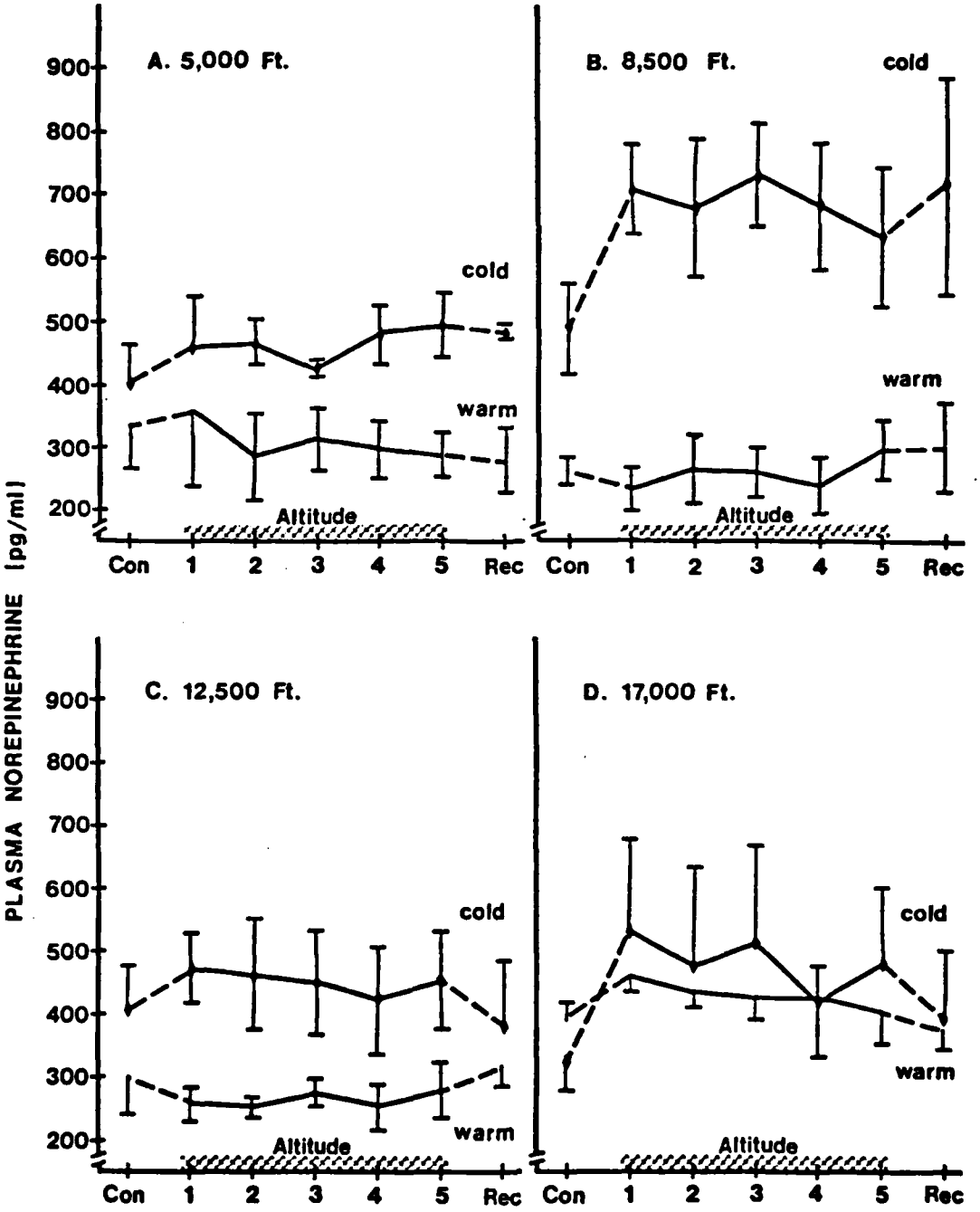


Figure 15. Mean plasma NE levels separated into cold and warm responders for each measurement period by altitude. Con = average of both control measurements. Rec = recovery measurement. Values represent means ± SEM. n=3.

CHAPTER IV

DISCUSSION

The subjects exhibited a level of hypoxemia commensurate with the exposure altitude and demonstrated physiological changes indicative of the level of hypoxia. Although arterial blood samples were not obtained, the venous blood samples were obtained from a resting muscle group. This provided a crude estimation of the level of oxygenation, but cutaneous vasoconstriction deluded this estimation in the colder subjects. At 5,000 and 8,500 ft, no significant changes in mean venous oxygen content, P_{CO2}, or pH were seen while heart rate slowly declined with time as the subjects rested in the chamber. This lack of change in blood chemistry would be expected if we consider that pulmonary and cardiovascular compensatory responses to hypoxic stress are not normally seen below 10,000 ft (547 torr) in resting subjects (3,23). Hyperventilation during the 12,500 ft exposure, as evidenced by a significant fall in P_{CO2} and a respiratory alkalosis, was able to improve blood oxygenation. Heart rate did not fall with time, indicating the beginning of relative tachycardia to hypoxia. At 17,000 ft, the subjects were no longer able to compensate for the diminished ambient P_{O2} even though hyperventilation was evident. The observed increase in heart rate is one of the physiological responses elicited by hypoxia in order to increase oxygen delivery to tissues in spite of the diminished P_{O2} (27,35).

Plasma epinephrine levels did not change with exposure to any of the experimental altitudes. This lack of adrenal medullary response to altitude exposure has been noted in other studies (7,9, 33,38). Hale et al. (16) found an inverse relationship between urinary epinephrine excretion and oxygen concentration in men exposed to oxygen levels of 15 to 100% delivered by mask (at ground level pressures). They found a significant effect due to the use of a mask and suggested that wearing masks augmented an increased adrenal medullary activity caused by the decreased oxygen tension. Other researchers have observed increased epinephrine release when hypoxia due to exposure to approximately 14,000 ft was combined with other stressors such as insulin infusion (29) and exercise (40).

Increased NE release with exposure to altitudes of 8,500 ft or greater has been documented in the literature (7,9,16,22,29,30, 33,38). Few reports have dealt with the effects of altitudes as low as 8,500 ft, but Daniels et al. (9) found increased urinary NE levels in exercising distance runners after the first day of exposure to 2200 m (7,218 ft). Pace et al. (33), working with humans exposed to 3,800 m (12,467 ft), observed increased urinary NE levels, but not until the second day of exposure. Furthermore, Higgens et al. (20) found no increase in urinary NE in subjects after three hours at 12,500 ft. The present study supports previous reports that an acute altitude exposure (one hour in the present study) is not sufficient stress to cause increased sympathetic activity at or below 12,500 ft.

The significant increase in plasma NE levels observed during the 8,500 ft exposure was difficult to justify in light of the lack of response at 12,500 ft. One explanation for this discrepancy is that

other stressors were not adequately controlled and may have caused the increased sympathetic activity. The classification of the subjects into warm vs cold responders revealed an increase in plasma NE levels at 8,500 ft only in the colder subjects, suggesting a cold induced, sympathetically mediated, peripheral vasoconstriction (17,39). The three cold responders were thus responsible for the increased plasma NE seen in the entire group exposed to 8,500 ft. Also, one subject (KG) had greatly elevated NE levels (control = 686 pg/ml) during his 8,500 ft exposure. This was partly explained by the fact that this exposure was his first in the series, and the morning of this run started with two aborted catheterizations before cannulation was successful. Therefore, the high plasma levels of NE seen at 8,500 ft were, in part, due to subject KG and the trauma of placing the catheter (5) along with the stress of the situation (14). Since the blood gas data, heart rates, and lack of AMS symptoms suggest that the subjects were not hypoxic, cold-induced sympathetically-mediated vasoconstriction and psychological stress probably accounted for the increase in plasma NE seen at this altitude.

A significant increase in plasma NE occurred immediately upon exposure to 17,000 ft. Since all subjects showed some increase in NE on ascent to that altitude, and since significantly higher levels of NE in the colder subjects vs the warmer ones were not observed (Fig. 12D), it is likely that this NE response was due to hypobaric hypoxia. The subjects also showed signs that they were hypoxic; increased heart rate, greater AMS response, decreased venous oxygen content, and a significant hyperventilatory response. Though every attempt was made to prevent the subjects from knowing the altitude of each exposure,

several of the subjects were able to determine when they were exposed to 17,000 ft. Since exposure to altitudes near 18,000 ft is associated with a headache by knowledgeable subjects (28), a psychological effect of anticipation cannot be ruled out during the 17,000 ft exposures. Why epinephrine levels did not also rise if anticipation is involved, is not understood.

Myles and Ducker (30) reported elevated urinary NE levels in unacclimatized rats exposed to 18,000 ft for six hours. Other researchers have also reported increased NE release with exposure to altitude (7,22,33,38). In most reports, however, the increase in NE did not occur until the second day of exposure (7,33,38). Though little work has been done on exposures as high as 17,000 ft, this study suggests that acute exposures at this altitude can elicit a sympathetic response.

Hoon et al. (22) had seen elevated urinary NE only in persons flown to an altitude of 3,658 m (12,000 ft) and who were also symptomatic for either AMS or early high altitude pulmonary edema (HAPE). They suggested that there might be a correlation between the increased NE and development of AMS and HAPE. The present study, however, shows no correlation between the degree of AMS and an increase in plasma NE. Since 12,500 ft elicited no increased sympathetic activity but a significant response to the AMS survey, it would be difficult to suggest any relationship between the two. Also, individual, high NE responses did not match individual, strong AMS sensations. No correlation indicating a direct or indirect relationship could be determined.

Frankenhaeuser (4,15) has done extensive work on the release of catecholamines during different types of stress, and the influence of released catecholamines on behavior. She suggested that epinephrine release was associated with coping with everyday stress situations as well as being involved in the highly stressful flight or fight situations (14,15). A lack of significant epinephrine release in the present subjects, and the absence of any significant response to the five psychological factors in the VAS survey, points to a lack of subjective sensation of stress during the exposures to acute hypobaric hypoxia. One of the problems of using a subjective analysis of feelings during an hypoxic situation is the loss of judgment and/or sense of euphoria which develops as the brain suffers from decreased oxygen (12,28). Perhaps, a better assessment of stress would be to have an observer judge the outward signs of stress as the subjects deal with a physical or mental task. A highly stressful task should be used since, in the present study, hypoxia did not produce a feeling of stress by itself. It would be interesting to determine changes in catecholamine levels during this type of environment, and this approach could be very useful.

The use of the VAS in assessing AMS provided new information on how early AMS symptoms present on exposure to hypobaria. While the degree of AMS found at the four different altitudes correlated with data obtained by other researchers (10), the short exposure time (only one hour) has not been previously considered sufficient to elicit AMS symptoms (19). Most of the work has been done on mountain climbers whose ascent rate was much slower than the 1,000 ft/min rate used in this study. The more rapid ascent rate could be responsible for the

earlier AMS responses seen in this study. This finding is of particular importance since The Federal Aviation Administration rules allow pilots to fly at 12,500 ft, unpressurized, for thirty minutes without the use of supplemental oxygen. The present evidence that AMS symptoms, especially ones such as muzzy, develop at this altitude within the maximum time allowable, suggests that a re-evaluation of the rules may be necessary.

The correlation between venous oxygen content and venous NE levels observed during the 5,000 and 8,500 ft exposures suggests that the degree of oxygen extracted from a vascular bed is related to the degree of sympathetic tone of that bed. When the vessels constrict, the tissue still requires oxygen for its metabolic needs and extracts greater quantities of oxygen per unit of blood then when it is perfused in excess (e.g. heat induced dilation). If one assumes near normal arterial oxygenation at 5,000 and 8,500 ft (Pa_{O2}, 80 torr), using the facts that the venous samples were taken from a resting vascular bed and that oxygen consumption reflects mainly basal metabolic needs, this correlation reflects the degree of sympathetic tone. With ascent to higher altitudes, the complications of decreasing availability of oxygen and possible hypoxia-mediated NE release override this mechanism and the correlation is lost. Excess catecholamines, which are not extracted and metabolized during passage through the lungs, would greatly interfere with this type of correlation. Furthermore, once the vascular bed is maximumly constricted, further increases in sympathetic activity would increase the plasma NE levels but not necessarily change venous oxygen extraction. In future attempts to study plasma catecholamines, the use of a heating

pad on all subjects (with a comfortable warm setting) would help eliminate the cutaneous vasoconstriction seen in this study. Furthermore, discarding data when there is any suspicion of psychological trauma is advised.

This study was designed to determine the catecholamine response to acute hypobaric hypoxia in resting subjects. Since the aircrew environment is rarely one of supine restfulness, without mental and physical stressors, further analysis of the multiple stresses involved is needed. The increased sympathetic activity seen at 17,000 ft also needs to be evaluated to determine whether the reduced pressure or the hypoxic stress is responsible. Further analysis of the psychological stressors and other human factors involved in the aircrew's environment is needed so that aircrew performance can keep up with aircraft technology.

CHAPTER V

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APPENDIX A

EXPOSURE SCHEDULE

Subject	ORDER OF EXPOSURE 1st	2nd	3rd	4th
RA	17,000 ft	5,000 ft	8,500 ft	12,500 ft
KG	8,500 ft	12,500 ft	5,000 ft	17,000 ft
BR	17,000 ft	8,500 ft	12,500 ft	5,000 ft
DR	8,500 ft	5,000 ft	12,500 ft	17,000 ft
DS	12,500 ft	17,000 ft	5,000 ft	8,500 ft
AT	8,500 ft	17,000 ft	5,000 ft	12,500 ft

APPENDIX B

INDIVIDUAL'S RESPONSE TO AMS SYMPTOMS
RA

Factor	Control	Difference from Control					
		Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Rec
NAUSEOUS							
5,000 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8,500 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12,500 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17,000 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LETHARGIC							
5,000 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8,500 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12,500 ft	0.0	0.0	0.0	0.0	0.0	6.0	0.0
17,000 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BREATHING EASY							
5,000 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8,500 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12,500 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17,000 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MUZZY							
5,000 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.500 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12,500 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17,000 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HEADACHE							
5,000 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8,500 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12,500 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17,000 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX C

INDIVIDUAL'S RESPONSE TO AMS SYMPTOMS
KG

Factor	Control	Difference From Control					
		Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Rec
NAUSEOUS							
5,000 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8,500 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12,500 ft	1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
17,000 ft	1.0	0.0	-1.0	-1.0	-1.0	-1.0	-1.0
LETHARGIC							
5,000 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8,500 ft	23.0	-5.0	-19.5	-21.0	-23.0	-22.0	-23.0
12,500 ft	0.0	1.5	0.0	3.0	0.0	0.0	2.0
17,000 ft	0.0	0.0	0.0	0.0	0.0	1.5	0.5
BREATHING EASY							
5,000 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8,500 ft	0.0	0.0	0.0	0.0	1.0	0.0	1.0
12,500 ft	0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
17,000 ft	0.0	4.0	6.0	15.0	17.5	12.5	1.5
MUZZY							
5,000 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8,500 ft	0.0	0.0	0.0	0.0	0.0	1.0	0.0
12,500 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17,000 ft	0.0	0.0	0.0	0.0	0.0	6.5	0.0
HEADACHE							
5,000 ft	2.5	-1.0	-1.0	1.0	2.0	0.5	0.5
8,500 ft	0.0	4.0	3.0	2.0	1.0	0.0	0.0
12,500 ft	0.0	0.0	2.5	4.0	4.5	6.0	4.5
17,000 ft	0.0	0.0	0.0	6.0	9.5	17.0	3.0

APPENDIX D

INDIVIDUAL'S RESPONSE TO AMS SYMPTOMS
BR

Factor	Control	Difference from Control					
		Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Rec
NAUSEOUS							
5,000 ft	0.5	1.5	1.5	1.5	2.0	2.0	1.5
8,500 ft	2.3	-0.8	0.7	0.7	1.2	-0.3	-0.3
12,500 ft	1.8	0.7	0.2	2.2	3.2	3.2	-0.8
17,000 ft	1.5	-0.5	0.5	0.0	-0.5	-1.0	0.5
LETHARGIC							
5,000 ft	4.5	0.5	0.5	0.5	1.5	0.5	-0.5
8,500 ft	4.8	1.2	3.2	5.2	2.2	4.2	-4.8
12,500 ft	9.5	2.5	-1.0	3.5	2.5	8.5	-6.5
17,000 ft	1.8	3.2	1.7	3.2	6.2	4.2	3.2
BREATHING EASY							
5,000 ft	2.3	0.7	-0.3	-0.8	-1.3	-0.3	0.7
8,500 ft	1.3	1.7	0.7	1.7	0.7	0.7	1.7
12,500 ft	1.8	4.2	2.2	2.2	5.7	5.2	0.2
17,000 ft	1.8	-0.3	-1.8	-0.3	0.2	0.2	-0.3
MUZZY							
5,000 ft	6.3	-1.8	1.7	-2.8	-0.8	0.7	-2.3
8,500 ft	4.3	-0.3	5.7	-0.3	-1.3	3.7	0.7
12,500 ft	5.3	-0,8	-0.3	8.2	2.2	20.7	-0.3
17,000 ft	1.0	-0.5	-1.0	0.0	0.5	0.5	-1.0
HEADACHE							
5,000 ft	1.5	0.5	0.5	0.0	1.5	0.5	-0.5
8,500 ft	2.8	1.7	-0.8	-1.3	-1.3	-2.3	-1.8
12,500 ft	1.3	1.7	0.7	2.2	7.7	13.7	3.7
17,000 ft	1.0	-0.5	0.5	0.0	2.0	0.0	0.0

APPENDIX E

INDIVIDUAL'S RESPONSE TO AMS SYMPTOMS
DR

Factor	Control	Difference from Control					
		Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Rec
NAUSEOUS							
5,000 ft	5.0	1.0	-2.0	-0.5	0.0	-0.5	1.0
8,500 ft	4.8	3.2	2.2	3.2	0.7	3.2	2.2
12,500 ft	5.0	3.0	1.0	0.5	1.0	3.0	1.0
17,000 ft	6.3	-0.8	8.2	12.7	18.7	12.2	-0.3
LETHARGIC							
5,000 ft	12.8	-0.3	0.2	2.2	-1.3	0.2	4.2
8,500 ft	23.0	0.0	3.0	-1.0	-1.0	2.5	3.0
12,500 ft	7.8	9.2	14.2	10.2	16.2	13.2	9.7
17,000 ft	9.8	6.7	20.2	26.2	36.2	27.2	8.7
BREATHING EASY							
5,000 ft	4.5	-0.5	0.5	0.5	-0.5	-0.5	0.5
8,500 ft	5.3	2.2	1.2	2.7	-0.7	1.2	-1.3
12,500 ft	7.5	6.5	9.5	4.5	0.0	-2.5	-1.5
17,000 ft	6.0	8.0	1.5	2.0	1.5	-1.0	-0.5
MUZZY							
5,000 ft	7.3	-1.3	-0.8	-1.3	-2.3	-3.3	-1.8
8,500 ft	5.0	3.0	2.5	1.5	-0.5	1.0	1.0
12,500 ft	7.0	0.0	11.0	23.0	22.0	22.0	1.0
17,000 ft	7.0	8.0	25.0	33.0	40.0	38.0	0.0
HEADACHE							
5,000 ft	6.0	-1.0	2.0	-1.0	-2.5	-2.5	0.0
8,500 ft	5.3	2.2	2.2	-1.7	-0.7	0.2	-0.7
12,500 ft	6.5	0.0	0.5	4.5	1.0	-0.5	0.5
17,000 ft	7.5	-2.0	2.5	2.5	-0.5	-1.5	-1.5

APPENDIX F

INDIVIDUAL'S RESPONSE TO AMS SYMPTOMS
DS

Factor	Control	Difference from Control					
		Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Rec
NAUSEOUS							
5,000 ft	0.0	0.0	0.0	0.0	0.0	0.0	0.5
8,500 ft	0.0	0.0	0.0	1.5	0.0	0.0	0.0
12,500 ft	1.3	0.7	0.7	0.7	1.7	1.7	-0.3
17,000 ft	0.0	0.0	0.0	0.0	0.0	1.0	0.0
LETHARGIC							
5,000 ft	3.3	0.2	1.7	-0.3	0.7	1.2	1.2
8,500 ft	0.0	0.0	0.0	1.0	4.5	2.5	2.0
12,500 ft	20.0	1.0	2.5	4.0	1.5	-3.5	-10.0
17,000 ft	8.5	3.5	9.5	6.5	4.5	2.5	-2.5
BREATHING EASY							
5,000 ft	0.5	-0.5	0.5	-0.5	-0.5	-0.5	0.0
8,500 ft	0.5	3.5	4.0	2.0	5.0	2.5	-0.5
12,500 ft	0.8	14.2	19.7	25.7	17.2	10.2	0.2
17,000 ft	0.0	11.0	19.5	19.5	13.5	10.5	0.0
MUZZY							
5,000 ft	0.0	0.0	0.0	0.5	0.0	0.0	0.0
8,500 ft	0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
12,500 ft	8.3	8.7	16.7	16.2	3.7	-5.3	3.7
17,000 ft	0.0	0.0	7.5	8.5	5.0	10.5	0.0
HEADACHE							
5,000 ft	0.0	0.0	1.5	0.0	1.0	0.5	0.0
8,500 ft	0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
12,500 ft	1.0	5.0	27.0	17.0	10.5	4.0	3.0
17,000 ft	0.0	3.0	10.5	5.0	0.5	2.0	0.0

APPENDIX G

INDIVIDUAL'S RESPONSE TO AMS SYMPTOMS
AT

Factor	Control	Difference from Control					
		Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Rec
NAUSEOUS							
5,000 ft	0.5	-0.5	-0.5	0.5	-0.5	0.5	-0.5
8,500 ft	0.3	-0.3	0.7	-0.3	-0.3	-0.3	-0.3
12,500 ft	1.0	0.0	0.0	1.0	0.0	0.5	-1.0
17,000 ft	1.0	-0.5	0.0	-0.5	0.0	0.0	-0.5
LETHARGIC							
5,000 ft	19.3	1.7	-0.3	5.7	5.2	0.2	2.7
8,500 ft	16.8	0.2	2.2	-1.8	2.2	-0.8	-1.8
12,500 ft	21.5	4.5	4.5	6.5	3.5	0.0	-2.0
17,000 ft	23.0	0.0	9.0	16.0	12.0	21.0	-1.5
BREATHING EASY							
5,000 ft	0.5	0.5	-0.5	C.5	0.5	0.5	0.5
8,500 ft	0.0	0.0	0.0	0.0	1.0	0.0	0.0
12,500 ft	1.3	0.7	0.7	1.7	-0.3	-0.3	-0.3
17,000 ft	0.5	3.5	2.0	3.0	0.5	4.0	0.5
MUZZY							
5,000 ft	21.5	1.5	2.0	5.5	4.5	1.0	-4.5
8,500 ft	13.5	3.5	7.5	3.5	7.5	5.5	6.5
12,500 ft	25.0	3.0	1.0	3.5	2.0	2.0	-5.0
17,000 ft	23.0	0.0	0.5	14.5	13.5	26.0	1.0
HEADACHE							
5,000 ft	0.0	0.0	0.0	1.0	1.0	1.0	1.0
8,500 ft	0.0	0.0	0.0	1.0	1.5	0.0	1.0
12,500 ft	0.5	0.5	1.5	2.5	0.5	1.5	1.5
17,000 ft	0.8	0.7	-0.3	0.2	1.7	6.7	0.2

APPENDIX H

VENOUS NE LEVELS
(pg/ml)

	Control	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Rec
5,000 ft							
RA	200	200	178	232	217	239	205
KG	487	597	527	457	546	579	496
BR	448	461	468	415	507	509	470
DR	286	332	411	410	396	401	499
DS	558	592	416	408	375	266	259
AT	248	285	271	302	301	355	378
Mean	371	411	379	371	390	392	385
±SEM	±44	±67	±53	±35	±50	±55	±52
8,500 ft							
RA	243	187	171	203	185	233	223
KG	687	825	895	889	877	847	1056
BR	432	725	596	626	550	503	532
DR	362	589	556	681	629	554	564
DS	242	218	274	248	210	273	236
AT	302	298	357	333	329	386	442
Mean	378	474	475	497	463	466	509
±SEM	±48	±112	±107	±112	±110	±92	±124
12,500 ft							
RA	446	286	269	295	303	362	359
KG	609	559	628	567	587	559	585
BR	330	377	334	294	298	306	252
DR	285	479	426	488	384	496	309
DS	201	206	221	231	182	237	267
AT	242	281	265	295	274	238	316
Mean	351	365	357	362	338	366	348
±SEM	±42	±55	±67	±54	±56	±55	±50
17,000 ft							
RA	307	344	365	357	352	403	372
KG	348	448	405	371	407	474	339
BR	461	814	656	822	588	716	602
DR	210	449	418	374	315	321	260
DS	456	504	487	421	347	307	349
AT	378	430	420	489	517	428	437
Mean	360	498	459	472	421	442	386
±SEM	±27	±67	±43	±73	±44	±61	±49

APPENDIX I

VENOUS E LEVELS
(pg/ml)

	Control	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Rec
5,000 ft							
RA	19	52	21	0	0	16	20
KG	31	0	58	86	47	61	41
BR	40	67	40	71	44	23	38
DR	94	77	78	90	60	91	103
DS	67	61	99	135	50	86	21
AT	62	48	28	65	25	106	22
Mean	52	51	54	75	38	64	41
±SEM	±8	±11	±12	±18	±9	±15	±13
8,500 ft							
RA	30	50	52	0	17	24	43
KG	82	87	126	49	94	110	33
BR	48	74	70	53	63	81	59
DR	37	59	77	69	53	59	74
DS	38	35	59	93	100	49	112
AT	50	53	46	27	70	0	50
Mean	47	60	71	49	66	54	62
±SEM	±7	±8	±14	±13	±12	±16	±12
12,500 ft							
RA	47	112	145	42	63	65	64
KG	66	40	34	34	25	32	71
BR	81	42	48	44	23	82	119
DR	127	153	74	74	83	74	79
DS	32	47	31	47	26	0	60
AT	54	23	86	34	76	67	87
Mean	68	70	70	46	49	53	80
±SEM	±11	±21	±18	±6	±11	±13	±9
17,000 ft							
RA	66	184	142	151	113	72	84
KG	9	39	37	76	83	21	53
BR	96	89	114	63	88	51	188
DR	111	95	60	108	130	75	57
DS	52	29	33	71	88	126	87
AT	23	55	53	73	58	66	61
Mean	53	82	73	90	94	69	88
±SEM	±12	±23	±18	±14	±12	±14	±21

APPENDIX J

VENOUS OXYGEN CONTENT
(vol %)

	Control	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Rec
5,000 ft							
RA	10.2	10.9	13.7	11.6	12.0	10.8	11.6
KG	8.9	4.7	4.6	6.6	4.1	2.8	3.9
BR	9.0	7.5	8.7	9.8	9.5	9.5	9.1
DR	10.3	9.0	7.1	7.5	8.8	6.5	5.9
DS	15.0	15.9	16.1	14.6	13.9	14.1	12.5
AT	11.7	12.2	12.1	11.5	10.5	10.5	8.5
Mean	10.8	10.0	10.4	10.3	9.8	9.0	8.6
±SEM	±0.8	±1.6	±1.8	±1.2	±1.4	±1.6	±1.3
8,500 ft							
RA	12.7	10.2	11.2	14.9	14.5	12.3	12.0
KG	5.3	3.2	2.5	2.5	1.7	6.7	4.4
BR	11.1	5.7	8.6	8.5	8.9	8.2	7.0
DR	5.8	6.9	5.0	5.4	4.8	4.5	3.2
DS	8.7	6.5	7.3	6.5	6.7	5.6	6.4
AT	11.2	7.4	7.4	7.8	8.0	6.0	8.4
Mean	9.1	6.6	7.0	7.6	7.4	7.2	6.9
±SEM	±1.0	±0.9	±1.2	±1.7	±1.8	±1.1	±1.3
12,500 ft							
RA	7.1	14.4	13.9	14.9	13.7	8.9	10.6
KG	5.8	2.5	2.7	2.9	3.5	2.8	4.5
BR	9.2	7.6	7.2	5.2	7.4	7.0	9.1
DR	10.9	7.5	5.7	7.2	5.8	6.9	9.3
DS	12.6	12.3	13.6	10.3	13.5	10.4	11.9
AT	13.2	11.1	11.3	10.9	12.7	11.2	12.5
Mean	9.8	9.2	9.1	8.6	9.4	7.9	9.6
±SEM	±0.8	±1.7	±1.9	±1.8	±1.8	±1.2	±1.2
17,000 ft							
RA	9.9	2.7	2.7	2.3	2.5	1.8	5.5
KG	13.1	9.0	10.7	13.5	15.0	13.2	18.1
BR	11.4	5.8	5.2	4.7	14.1	3.7	8.6
DR	10.0	7.6	4.6	5.2	3.5	4.9	7.8
DS	12.8	7.5	8.4	9.4	11.8	11.9	12.3
AT	7.2	5.3	5.6	5.2	5.8	7.5	10.1
Mean	9.9	6.3	6.7	6.7	7.1	7.2	10.4
±SEM	±1.1	±0.9	±1.6	±1.6	±2.1	±1.9	±1.8

APPENDIX K

VENOUS P_{O2} LEVELS (Torr)

	Control	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Rec
5,000 ft							
RA	37	38	45	42	47	40	40
KG	33	23	22	24	20	18	21
BR	31	28	31	32	30	31	29
DR	35	31	27	30	33	29	24
DS	52	54	58	51	48	48	43
AT	38	41	39	39	34	33	29
Mean	38	35	35	35	33	32	30
±SEM	±3	±6	±6	±5	±5	±5	±4
8,500 ft							
RA	39	37	37	47	47	39	39
KG	22	17	17	14	14	26	19
BR	36	24	32	30	35	31	27
DR	-	-	-	-	-	-	-
DS	35	25	28	26	27	24	26
AT	35	31	27	30	28	27	28
Mean	33	24	26	25	26	27	25
±SEM	±2	±3	±3	±4	±4	±2	±2
12,500 ft							
RA	20	42	46	46	42	21	29
KG	24	16	13	15	14	15	19
BR	32	26	26	22	27	24	28
DR	35	29	25	28	25	27	31
DS	41	43	42	33	42	40	42
AT	41	34	32	32	35	32	36
Mean	32	30	28	26	29	28	31
±SEM	±2	±5	±5	±3	±5	±4	±4
17,000 ft							
RA	34	15	14	12	15	8	22
KG	43	29	32	39	43	37	67
BR	34	23	23	21	18	17	27
DR	31	24	18	18	15	18	26
DS	47	28	30	32	36	38	43
AT	27	21	22	22	21	25	33
Mean	36	22	21	21	21	21	30
±SEM	±2	±2	±3	±3	±4	±5	±4

APPENDIX L

VENOUS P_{CO2} LEVELS (Torr)

	Control	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Rec
5,000 ft							
RA	48	48	47	46	48	51	49
KG	65	65	67	67	67	66	66
BR	56	55	54	55	52	52	54
DR	59	59	61	60	58	59	62
DS	46	43	41	41	44	44	44
AT	48	49	50	52	52	52	54
Mean	53	53	53	54	54	54	55
±SEM	±2	±3	±4	±4	±3	±3	±3
8,500 ft							
RA	54	56	53	52	49	51	55
KG	61	60	62	68	62	62	58
BR	51	54	50	50	49	49	50
DR	52	49	50	50	49	49	49
DS	52	56	58	57	56	58	56
AT	55	57	57	56	57	55	58
Mean	54	55	55	56	54	54	54
±SEM	±1	±2	±2	±3	±2	±2	±2
12,500 ft							
RA	60	50	46	48	47	52	49
KG	57	57	56	56	58	55	56
BR	59	57	56	54	54	55	58
DR	50	50	46	46	46	47	48
DS	48	42	42	45	42	44	47
AT	50	51	50	50	44	48	50
Mean	54	51	49	50	49	50	51
±SEM	±2	±2	±2	±2	±3	±2	±2
17,000 ft							
RA	51	55	53	52	50	51	51
KG	57	46	42	38	35	36	41
BR	52	56	52	52	53	50	54
DR	64	59	58	59	58	57	64
DS	49	50	45	42	40	40	48
AT	59	56	54	53	54	52	52
Mean	54	54	51	49	48	48	52
±SEM	±2	±2	±2	±3	±4	±3	±3

APPENDIX M

VENOUS pH

	Control	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Rec
5,000 ft							
RA	7.34	7.34	7.33	7.33	7.32	7.30	7.32
KG	7.36	7.36	7.36	7.36	7.37	7.36	7.34
BR	7.34	7.36	7.36	7.35	7.37	7.37	7.36
DR	7.36	7.35	7.34	7.34	7.34	7.33	7.33
DS	7.39	7.39	7.39	7.39	7.39	7.37	7.37
AT	7.34	7.34	7.33	7.32	7.32	7.34	7.33
Mean	7.35	7.36	7.35	7.35	7.35	7.34	7.34
±SEM	±.01	±.01	±.01	±.01	±.01	±.01	±.01
8,500 ft							
RA	7.32	7.32	7.34	7.36	7.37	7.35	7.33
KG	7.32	7.30	7.29	7.25	7.25	7.30	7.31
BR	7.32	7.31	7.33	7.33	7.35	7.35	7.36
DR	7.35	7.35	7.36	7.36	7.36	7.35	7.36
DS	7.37	7.36	7.33	7.34	7.33	7.35	7.33
AT	7.30	7.28	7.29	7.31	7.31	7.32	7.30
Mean	7.33	7.32	7.32	7.32	7.33	7.34	7.33
±SEM	±.01	±.01	±.01	±.02	±.02	±.01	±.01
12,500 ft							
RA	7.29	7.36	7.36	7.37	7.37	7.34	7.36
KG	7.34	7.35	7.35	7.36	7.39	7.36	7.35
BR	7.33	7.33	7.34	7.35	7.35	7.36	7.35
DR	7.35	7.36	7.37	7.37	7.36	7.37	7.36
DS	7.35	7.40	7.40	7.37	7.40	7.38	7.38
AT	7.36	7.36	7.37	7.40	7.41	7.39	7.39
Mean	7.34	7.36	7.36	7.37	7.38	7.37	7.36
±SEM	±.01	±.01	±.01	±.01	±.01	±.01	±.01
17,000 ft							
RA	7.36	7.34	7.37	7.35	7.36	7.37	7.36
KG	7.37	7.40	7.42	7.45	7.47	7.44	7.41
BR	7.37	7.35	7.38	7.38	7.35	7.36	7.35
DR	7.38	7.39	7.41	7.40	7.42	7.42	7.38
DS	7.37	7.37	7.40	7.40	7.43	7.44	7.36
AT	7.34	7.35	7.36	7.36	7.37	7.36	7.35
Mean	7.36	7.36	7.38	7.38	7.38	7.38	7.36
±SEM	±.004	±.01	±.01	±.01	±.02	±.02	±.01

APPENDIX N

RESPIRATORY RATES
(breaths/min)

	Control	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Rec
5,000 ft							
RA	7	6	5	5	5	6	7
KG	11	13	12	12	11	12	11
BR	13	14	14	15	14	13	13
DR	11	8	12	12	11	11	9
DS	11	13	12	10	15	13	11
AT	11	11	13	11	11	12	11
Mean	11	11	11	11	11	11	10
±SEM	±1	±1	±1	±1	±1	±1	±1
8,500 ft							
RA	8	7	6	7	7	7	6
KG	14	11	12	14	13	13	14
BR	13	11	13	13	13	14	13
DR	9	7	7	10	9	7	8
DS	9	12	10	12	9	10	11
AT	11	12	11	10	11	11	11
Mean	10	10	10	11	10	10	10
±SEM	±1	±1	±1	±1	±1	±1	±1
12,500 ft							
RA	7	7	7	6	6	6	6
KG	15	16	17	16	16	15	14
BR	13	15	14	15	13	14	12
DR	12	11	10	10	9	10	10
DS	13	13	13	13	13	13	11
AT	12	12	11	13	12	12	11
Mean	12	12	12	12	11	11	11
±SEM	±1	±1	±1	±2	±1	±1	±1
17,000 ft							
RA	8	8	9	9	8	9	7
KG	13	13	15	13	16	13	13
BR	10	14	15	15	15	14	13
DR	12	13	13	12	13	13	8
DS	15	12	8	9	11	13	11
AT	11	11	11	13	14	12	10
Mean	12	12	12	12	13	12	10
±SEM	±1	±1	±1	±1	±1	±1	±1

APPENDIX O

BLOOD PRESSURES
(Torr)

		Control	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Rec
5,000 ft								
Systolic/Diastolic	RA	98/57	96/56	98/60	96/58	96/60	98/56	96/58
	KG	108/69	104/70	106/66	106/70	110/68	110/72	108/70
	BR	108/74	110/78	110/78	106/68	106/78	108/80	114/78
	DR	107/67	104/70	104/70	102/70	106/70	108/72	108/74
	DS	97/58	96/62	94/62	92/60	94/64	94/60	90/60
	AT	110/72	110/70	112/76	110/76	112/76	112/76	106/74
	Mean	105/66	103/68	104/69	102/67	104/69	105/69	104/69
	±SEM	±2/±2	±3/±3	±3/±3	±3/±3	±3/±3	±3/±4	±4/±3
Mean	RA	71	69	73	71	72	70	71
	KG	82	81	79	82	82	85	83
	BR	85	89	89	81	87	89	90
	DR	81	81	81	81	82	84	85
	DS	71	73	73	71	74	71	70
	AT	85	83	88	87	88	88	85
	Mean	79	79	81	79	81	81	81
	±SEM	±2	±3	±3	±3	±3	±3	±3
8,500 ft								
Systolic/Diastolic	RA	90/52	84/56	84/60	92/56	90/56	92/60	94/58
	KG	110/75	112/82	112/76	112/76	108/74	110/78	100/70
	BR	115/83	116/76	114/78	116/78	108/76	108/76	118/82
	DR	116/79	118/81	117/81	117/72	116/78	117/78	114/76
	DS	108/58	94/54	98/54	100/58	104/58	96/64	100/60
	AT	109/72	110/76	114/76	112/76	110/76	112/76	110/80
	Mean	108/70	106/71	107/71	108/69	106/70	106/72	104/71
	±SEM	±3/±3	±6/±5	±5/±5	±4/±4	±4/±4	±4/±3	±4/±4
Mean	RA	65	65	68	68	67	71	70
	KG	87	92	88	88	85	89	80
	BR	94	89	90	91	87	87	94
	DR	92	93	93	87	91	91	89
	DS	75	67	69	72	73	75	73
	AT	84	87	89	88	87	88	90
	Mean	83	82	83	82	82	84	83
	±SEM	±3	±5	±5	±4	±4	±3	±4

APPENDIX O (cont.)

		Control	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Rec
12,500 ft								
Systolic/Diastolic	RA	85/47	90/54	90/46	80/38	86/46	88/56	86/56
	KG	107/67	102/68	108/70	110/70	110/70	110/72	112/74
	BR	119/77	120/78	118/78	122/80	120/74	118/80	116/76
	DR	102/60	104/68	105/68	105/68	102/68	108/66	110/68
	DS	100/58	100/58	96/58	102/62	100/60	100/60	100/60
	AT	112/76	114/78	112/76	106/74	112/74	110/70	112/74
	Mean	104/64	105/67	105/66	104/65	105/65	106/68	106/68
	±SEM	±3/±3	±4/±4	±4/±5	±6/±6	±5/±4	±4/±4	±5/±3
Mean	RA	60	66	61	52	59	67	66
	KG	80	79	83	83	83	85	87
	BR	91	92	91	94	89	93	89
	DR	74	80	80	80	79	80	82
	DS	72	72	71	75	73	73	73
	AT	88	90	88	85	87	86	87
	Mean	77	80	79	78	78	81	81
	±SEM	±3	±4	±5	±6	±5	±4	±4
17,000 ft								
Systolic/Diastolic	RA	91/59	92/62	84/60	82/60	90/58	86/58	88/58
	KG	111/73	112/76	110/76	114/76	114/78	116/78	112/76
	BR	116/79	116/80	118/79	119/76	116/78	117/76	118/80
	DR	107/72	108/68	96/62	92/60	96/62	100/64	98/70
	DS	94/60	88/52	86/56	82/52	88/58	90/56	96/58
	AT	113/77	102/72	110/76	110/76	110/78	107/76	116/78
	Mean	105/70	103/68	101/68	100/67	102/69	103/68	105/70
	±SEM	±3/±2	±5/±4	±6/±4	±7/±4	±5/±4	±5/±4	±5/±4
Mean	RA	70	72	68	67	69	67	68
	KG	86	88	87	89	90	91	88
	BR	91	92	92	90	91	90	93
	DR	84	81	73	71	73	76	79
	DS	71	64	66	62	68	67	71
	AT	89	82	87	89	89	86	91
	Mean	82	80	79	78	80	80	82
	±SEM	±3	±4	±5	±5	±5	±5	±4

APPENDIX P

HEART RATES
(beats/min)

	Control	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Rec
5,000 ft							
RA	51	54	50	50	49	51	47
KG	65	60	58	58	60	54	53
BR	66	69	66	63	63	59	63
DR	62	58	58	57	58	51	52
DS	80	76	72	70	68	60	68
AT	67	65	64	67	62	64	61
Mean	65	64	61	60	60	57	57
±SEM	±3	±3	±3	±3	±3	±2	±3
8,500 ft							
RA	55	55	52	51	47	52	47
KG	54	50	54	56	58	55	56
BR	63	67	62	64	60	59	66
DR	50	50	46	48	44	46	47
DS	75	77	80	71	71	67	72
AT	67	64	61	65	58	60	56
Mean	60	61	59	59	56	57	57
±SEM	±3	±4	±5	±4	±4	±3	±4
12,500 ft							
RA	53	60	59	55	55	58	56
KG	54	62	61	58	58	60	51
BR	68	65	61	65	60	59	75
DR	59	56	56	56	58	55	51
DS	68	69	75	68	69	69	65
AT	63	68	69	71	66	68	63
Mean	60	63	64	62	61	62	60
±SEM	±2	±2	±3	±3	±2	±2	±4
17,000 ft							
RA	46	57	64	57	58	62	49
KG	61	78	65	69	67	62	57
BR	67	78	66	65	66	64	68
DR	68	66	71	69	68	71	56
DS	72	76	70	70	68	69	62
AT	60	68	62	65	65	67	57
Mean	62	71	66	66	65	66	58
±SEM	±3	±3	±1	±2	±2	±2	±3

APPENDIX Q

CONSENT TO SERVE AS A SUBJECT IN RESEARCH

I consent to serve as a subject in the research investigation entitled: Plasma Catecholamines and Stress Assessment in Men Exposed to Moderate Altitudes.

The nature and general purpose of the experimental procedure and the known risks involved have been explained to me by _____. He/she is authorized to proceed on the understanding that I may terminate my service as a subject in this research at anytime I so desire.

I understand the known risks are the possibility of acute baron-sinusitis or barotitis media, venous puncture complications or acute mountain sickness and the extremely remote possibility of high altitude pulmonary edema or decompression sickness.

I understand also that it is not possible to identify all potential risks in an experimental procedure, and I believe that reasonable safe-guards have been taken to minimize both the known and the potential but unknown risks.

Witness_____ Signed_____

Date of birth_____

Date_____

If subject is injured in the course of the research investigation and he/she contends that Colorado State University or an employee thereof is at fault for the injury, the subject must file a claim within 90 days of the date of the injury with the State Attorney General and the State Board of Agriculture. The University carries liability insurance to compensate subjects for such injuries. Details on this procedure to obtain this compensation is available through the Office of Legal Counsel (303) 491-5284. The University cannot otherwise compensate subjects for their injuries, and subjects must depend on their own health and disability insurance for compensation for injuries sustained in the course of the research investigation which are not the fault of CSU or its employees. For any questions, contact the Office of the Committee on Human Research, Colorado State University (303) 491-7162.

APPENDIX R

RELEASE AGREEMENT

I, the undersigned, hereby release Colorado State University, its officers, agents, and employees from any and all liability arising from my participation (as a voluntary subject) in an experiment which requires me to enter a high and low pressure chamber. I fully understand the nature of the experiment in which I am a (participant) (voluntary subject) and am aware of the potential hazards associated with studies conducted under conditions of high and low atmospheric pressures.

I have undergone all appropriate medical tests and examinations to establish that I am in suitable physical condition to act as a (voluntary subject) (participant) in this high and low pressure experiment.

_____ _____

Date Signature

APPENDIX S

DATE _____

CATECHOLAMINE STUDY

CHAMBER DATA SHEET

	BLOOD PRESSURE	PULSE	RESPIRATIONS
CONTROL 1			
CONTROL 2			
ALTITUDE 1			
ALTITUDE 2			
ALTITUDE 3			
ALTITUDE 4			
ALTITUDE 5			
RECOVERY			

APPENDIX T

DATE _____

CATECHOLAMINE STUDY

BLOOD DATA SHEET

	pH	pCO_2	pO_2/C_{O2}	HCT.
CONTROL 1				
CONTROL 2				
ALTITUDE 1				
ALTITUDE 2				
ALTITUDE 3				
ALTITUDE 4				
ALTITUDE 5				
RECOVERY				

AT	50	53	46	27	70	0	50
Mean	47	60	71	49	66	54	62
±SEM	±7	±8	±14	±13	±12	±16	±12
12,500 ft							
RA	47	112	145	42	63	65	64
KG	66	40	34	34	25	32	71
BR	81	42	48	44	23	82	119
DR	127	153	74	74	83	74	79
DS	32	47	31	47	26	0	60
AT	54	23	86	34	76	67	87
Mean	68	70	70	46	49	53	80
±SEM	±11	±21	±18	±6	±11	±13	±9
17,000 ft							
RA	66	184	142	151	113	72	84
KG	9	39	37	76	83	21	53
BR	96	89	114	63	88	51	188
DR	111	95	60	108	130	75	57
DS	52	29	33	71	88	126	87
AT	23	55	53	73	58	66	61
Mean	53	82	73	90	94	69	88
±SEM	±12	±23	±18	±14	±12	±14	±21

END